RESHAPING MAN'S HERITAGE

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Biology in the Service of Man

by

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London
GEORGE ALLEN & UNWIN LTD

FIRST PUBLISHED IN 1944

BOOK
PRODUCTION
WAR ECONOMY
STANDARD

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PRINTED IN GREAT BRITAIN
in 11-Point Fournier Type
BY UNWIN BROTHERS LIMITED
WOKING

INTRODUCTORY NOTE

MAN forms part of a web of living things, plants, and animals, on some of which he depends for food and clothing. Other creatures, especially viruses, live upon him: he must master them or they will master him. Now man is continually refashioning the web: growing better plants and improving the soil in which they live, breeding finer animals, and searching for the best animal foodstuffs: in a word, reshaping the heredity and environment. He has explored the world, and by the invention of fire, clothing, houses, central heating, refrigeration, he has progressed towards independence of climate. Chemical science gives man mastery of the world of materials. Atoms are reshuffled to meet his needs. Man uses his brains to save his muscles, first by taming other animals to work for him, later by harnessing the energy of wind and water, coal and oil.

Increasingly, in all of these fields of human struggle, scientific theory is applied to practice, and bears fruit in ever greater freedom and control of man's heritage.

In this book which consists of a series of broadcast talks, a group of distinguished scientists discuss the application of the latest discoveries in biology to the life of man. The aspects of the subject covered include man's heritage, man's food, the good earth, reshaping plants and animals, the conquest of the germ, the banishment of pain and preventive medicine.

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I

MAN'S HERITAGE

By H. G. Wells

I have tried to prepare you for what I am going to say by a synopsis. It may be well to recall that synopsis and explain that I am an extreme revolutionary, who considers the doctrines of the Communist Party, as you get them for example in the *Daily Worker*, fifty years behind the times. I don't ask you to prepare for a new world, because I realise that a New World is here now. The question is whether our species, we, our children and our children's children, can adapt ourselves and conquer the new world, or whether we are going to spin down this vortex to extinction. Extinction which has been the fate of all the mighty races of animals that have lorded it over the world in the past.

What, briefly, is this New World, this new state of affairs that confronts mankind? It has a threefold aspect. *First*, there is what is called the abolition of distance. Things have become *simultaneous throughout the earth.* Thirty years ago, to think of one super government throughout the world, was an impossible dream. Now it is an imperative necessity. *Next*, comes the enormous increase of available power, which at present is used mainly for destruction. All the mechanical power, wind-power, horse-power, water-power, used in the England of Queen Elizabeth for a week, would not equal that released in a moment by one eight thousand pound bomb. *Thirdly*, the unskilled work of slaves and suchlike toilers can be and is being largely superseded by power-driven mechanism. The old social pyramid has vanished. Mankind has no further use for serfs and slaves. The new world ahead must be therefore an equalitarian society. These are not *views* I am stating, but manifest facts. For ten or twelve thousand years, not more, since men took to agriculture and organized warfare, there has been no real human community. There has been a world of masters and men, what Disraeli called the Two Nations. *Now*, for these three reasons I have stated, there is no choice before mankind but a world-wide control of power and production—world-wide, no less—and a world-wide scrapping of our inheritance of hates and aggressions that began less than a thousand generations ago, when wars began. We have to nerve ourselves for that, and there is no other way for us. Even if you decided to avoid having children and get into some safe corner and eat, drink and be merry, for to-morrow you die, you might have difficulty in finding that safe corner and getting the stuff and the merriment. Need I enlarge on that to-day?

Obviously, this world control must be something over and above the patchwork of governments we inherit. They arose from militant necessities! they remain militant and competitive. But plainly it is the common sense of the world situation that, over and above these old divisions, a group of commissions to rehabilitate our disordered world should be established as soon as possible by the victors in the present struggle. To these commissions, all the governments of the world must surrender their sovereign rights to practise economic and political aggression against one another. That has been done already within the U.S.A., within the U.S.S.R., and in Great Britain, and some but not all of the Dominions, which have replaced the old British Empire, where people of the most varied creeds, cultures and languages live in free and open co-operation. It has to be done, and done still more completely throughout the world.

I believe it can be done, and that, as our old world dies about us, it will be done. And so I will go on to prelude, in general terms—for I am the mere compère of this discussion—the vast yet entirely practicable possibilities the succeeding speakers in this series will unfold to you. I will illustrate our conjoint undertaking by two items among the vast possibilities of the New World.

Professor Armstrong used to take my socialistic optimism down a peg, by pointing out that human productivity depends upon the supply of phosphates in the world, and that is a limited and dwindling quantity.

Sir Frederick Keeble has been discussing this recently. So far as our present methods of conducting human affairs go, the process is as follows. Every year a certain limited amount of phosphates is dissolved out of disintegrating rocks, brought to the surface and made available for plants. Flood and stream bear much of it directly to the sea, but some is intercepted, forest and pasture flourish, and animal life consuming this green stuff increases until it outruns the supply. Then the vitality of the land diminishes. Long before winter, and in sunny climates where there is no winter, pasture, gardens, trees go brown, feed for the cattle diminishes, milk decreases.

The soluble phosphates have found their way into the sea. They are seized upon by a swarming microscopic pelagic life, foraminifera, diatoms, and the like, which supplies the food for a huge proliferation of fishes. This again increases to a maximum and declines. Fisheries intercept a fraction of this phosphorus; the greater part of it forms insoluble compounds with other substances, bones, shells, and so forth, and sinks slowly into the abyss beyond recovery.

Human life is an incident in the passage of phosphorus from the at present inaccessible rocks, lying below those in the geological series, to the abyss. In a fragmentary way, we supplement the supply by the use of such natural fertilisers as Chilean guana, now almost exhausted, phosphates which have been snatched back for us at the last moment by fish-eating sea fowl, or we resort to basic slag and kindred foundry products to enrich our fields. A good farmer heartens his ground in this way, his neighbour may or may not do the same. But directly we turn our minds to the possibilities of a collective world control of nature, we realize that the meagre supplies of soluble phosphates from decaying rocks, volcanic upheaval and the like, upon which all life—*all life*—hitherto has subsisted, may be enormously increased and replaced by an immeasurably vaster abundance. It is only a question of going deep.

We can imagine a united, empowered and altogether more intelligent New World driving shafts deep into the earth, pursuing the lurking phosphates into those depths from which they now emerge so meagrely and reluctantly, we can imagine a smiling succession of fertilities, and so easy will food-getting become that with the greater part of our planet our kind will make a pleasant garden, a variety of habitations for their ever more varied and expanding lives.

Let me turn now to the horrible and tragic waste of human lives that has been going on since, five hundred generations ago, war and subjugation broke upon mankind. This period of five hundred generations, a mere yesterday in the long history of this globe, was spent for the great majority of human beings in abjection and frustration. Winwood Reade, in his immortal book, has called these twelve or fifteen thousand years, *The Martyrdom of Man*, and maybe it was a necessary schooling for our species. I do not recognize the necessity, but anyhow, this ugly interlude in the life of our planet is mounting now to its catastrophic end, and a further question, far more fundamental even than the phosphate question, is what has to be done with the immense majority who are being emancipated by the New World, a majority from which even the laziest and most inveterately stupid ruling-class minds surely cannot expect a return to subjection, service and uncritical acquiescence.

Our human heritage indeed is a devastated estate of undeveloped or distorted possibilities. One can only guess what proportion of human beings in the past missed the slightest chance of self-development, how many mute inglorious Miltons died in silence, how many potential Newtons never learnt to read. The supreme task before our awakening minds is the re-education of the world. Given world unity and world sanity, that would be an easy task. We have in the radio, the film, in the facility for the rapid transport of material and specimens, all that is needed to cover the whole world with schools, and in the multitude of quickened minds this struggle has evoked, a supply of men and women who have discovered that by teaching we learn. There are claptrap phrases about backward races and inferior peoples. These are the foolish excuses by which those who still hope to go on at an advantage over their fellow creatures camouflage their own foolishly base dreams. There are no backward races. All over the earth babies start from scratch, full of distinctive and untried possibilities, which the New World will develop eagerly. Here you will find folks with a superlative sense of rhythm like the negro; here great mechanical genius, like the Australian black fellow; here a genius for system like the French, or an obstinate unteachable originality of thought like the English. If our world educational organization has its schools everywhere, and nothing but imaginative meanness makes that even *seem* impossible, instead of that small fraction of people, we shall have the majority of mankind, inventing, responding, contributing with honour and self-respect to the rehabilitation of our so nearly lost inheritance.

And what our physically and mentally emancipated race will make of its collective property dazzles and blinds the imagination. I will not venture any suggestions upon the art and particularly the architecture of the possible future. About music and mathematical science I can say nothing. But I do know, and I am convinced that those who will speak in this series will endorse the statement, that there is no field in the vast realm of experimental science where there is not a crying need for multitudes of workers to go into problems for which at present men are lacking. In medical science, for example, you hear again and again, "We don't know yet. That waits to be worked out." I am interested in one little corner of medical work. I am President of the Diabetic Association, and what we know of diabetes is a jungle of unanswered questions, because we have not the scientific workers and resources available to answer them. Given a unified world order, disease after disease will vanish from the world for ever. There are possible enlargements of individual human faculty with which I have no time to deal.

Then great as are the achievements of chemistry, of mineralogy, of prospecting and exploration, I believe every research chemist will echo Sir Isaac Newton's saying, that he is as yet merely picking up pebbles on the beach of an unfathomable ocean. Face up to your Inheritance, and this ever-growing knowledge, this ever-growing Power, will be among the first fruits of your estate.

And what stands in the way of these achievements?

Fear.

When I say Fear, I mean Fear of Life. The experiences of the past few years help us to realize that "All a man hath will he give for his life" is a falsity. Great multitudes fear life more than death. Death to many people has presented itself as a form of escape from living. Apart from suicide and self-exposure, there is for most of us, after the early enterprise of healthy youth, a dread of novel problems. We have to be called up to them, forced to face them, and we crave to return to the old conditions as soon as possible. Multitudes of people have their minds deliberately crippled from birth. They are told they must *not* read; they must *not* listen. Down the ages, there is a long record of book-burning, and the persecution of victims who have had no right to reply. The Nazi book burning was only the last chapter in the black record of intolerance that holds us back from our estate.

So much for two broad aspects of our inheritance. My role in this series is that of a mere introducer. I introduce not a picture but a frame. In that frame we shall be privileged to study the detailed possibilities before mankind, with men who combine high scientific standing with practical experience. I have had glimpses of the material in store and I take over my proper role of listener and learner very gladly.

For our concluding talk, Dr. Julian Huxley, whose recent book, *Evolution*[1] is indispensable to every serious student as a compendium of contemporary biological ideas, will sum up for us what he concludes to be the present trend of evolutionary forces in the case of our own species. We may not agree with him in everything. Dr. Haldane, for example, who is one of our contributors, differs from him upon certain interpretations as I do upon others, but that does not matter in the least for such a discussion as this. Dr. Huxley will sum up for himself, and the summing up of the whole must be done by everyone who has listened in to our conference. We are learners together, we are accepting nothing cut and dried, and each one of us must form his own final conclusions.

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[1] London: George Allen & Unwin, Ltd.

II

MAN'S FOOD

By J. C. DRUMMOND AND W. F. CRICK

DRUMMOND: I wonder, Crick, if your experience is the same as mine. Do you meet a lot of people who're surprised by the good record of health shown by the population during the war in spite of food restrictions.

CRICK: Yes—and I can well understand their surprise.

DRUMMOND: It's not, of course, in the least surprising to nutrition experts, because they knew it was possible to plan a war-time diet so that everybody should be able to get the food needed for their health even if the diet had to be a lot plainer than in the piping times of peace.

CRICK: Yes: that's all very well, Drummond, but when do you regard a man as being decently fed?

DRUMMOND: Well, we scientists think in terms of certain basic foods essential for health and these have formed the foundations of our food plans for the war. Take milk. Sir John Orr has rightly called it the keystone to our nutrition. Next in importance comes, not meat, as so many people think, but vegetables—potatoes, greenstuff and carrots—all of which really are part of our first line of defence of health.

CRICK: Now let's be quite personal about this, Drummond. Is what you've just said the voice of Drummond or is it an agreed scientific opinion? Can you say that nutritionists by and large are agreed on the fundamentals of a good square meal?

DRUMMOND: Well, you know, we scientists do squabble now and then. But on this question we speak with one mind—not only in this country, but the world over. I'd challenge anyone to produce a nutrition expert of standing who doesn't put milk—and with milk, cheese—and vegetables right at the top of the list of essential foods.

Crick: But that's the direction in which we were moving in practice even before the war. There was a big expansion in the consumption of the goods you've mentioned.

Drummond: Yes, but with one big difference. In the twenty years or so since 1914 it's true the consumption of milk went up about 20 per cent, and fruit and vegetables something between 60 and 70 per cent. In one way we nutrition experts were very pleased to see these changes; but what disturbed us a bit was that, by and large, these increases reflected improvement in the diet of the relatively well-to-do families. The poorer people hadn't nearly such a good record.

Now the important thing about the last three years is that by one means or another we've been able to improve the diet of everybody—improve it nutritionally that is.

Crick: Precisely. That, of course, is exactly what the economist would suspect. The pre-war improvement was disorderly and uneven; the result of a growing appreciation of the importance of the foods you've mentioned hampered by conditions which in effect spelled world depression and large-scale unemployment, so that the rise in the standard of living was concentrated on those who were fortunate enough to be in work.

During the war the improvement—though largely due to steadier employment and better earnings has been guided, it has resulted from scientific management of limited resources through rationing, priorities, price control, and so forth. The principle can be put in five words: "Fair shares and full shares!"

Drummond: Yes: As you know as well as I do, Crick, that milk is now much more fairly distributed than before. The National Milk Scheme, the big expansion of the Milk in Schools Scheme, special priorities for expectant and nursing mothers and very young children, and so on. All these were part of a big plan to get the milk to those who needed it most. Of course, although our people are drinking nearly 30 per cent more milk than they did before the war, they still are not getting all the nutrition experts want them to have. So we've still a long way to go.

Crick: Now this is where you and I find common ground, Drummond, for all these measures for levering up standards of consumption are very much in line with a trend of economic thought and action which was already in sight before the war. The urgency of the need from the nutritional point of view was sufficiently obvious from the surveys made in various countries. Here and indeed in the United States—the richest country in the world—I believe it was concluded that only about two-thirds of the population were obtaining before the war a diet that could be considered barely adequate for health.

Drummond: Yes, that's so.

Crick: It's not surprising, I think, in view of that fact on the one hand and the world depression on the other, that economists should have been thinking more and more that the direct enlargement of consumption was the right and most promising approach to economic advancement. That, no doubt, is one reason for the experiments that were going on in various countries—such as the food stamp plan in the United States and the rebate-card system in Sweden.

Drummond: Yes, Crick. Everybody recognizes that the economists have been feeling their way towards a solution of this big problem in a variety of directions. The Stamp-plan of the United States was really brought in as a means of getting rid of some of the large agricultural surplus, but in fact it did benefit a great many poor families, didn't it?

Crick: It had, as you say, a double purpose. The scheme was this: that anyone in receipt of public relief could, if he liked, instead of taking a dollar in cash, take a dollar's worth of orange-coloured stamps, to which were added 50 cents' worth of blue stamps.

The orange stamps could be spent on any foodstuffs at any shop at the ordinary prices. The blue stamps could be spent on any foodstuffs in a list published by the Department of Agriculture. The listed commodities were chosen partly for their special food value, and partly by reference to the local agricultural situation whether there happened to be a surplus or a shortage of a particular commodity. The net result was a very much expanded consumption, exactly where it was wanted by poor families, and of those commodities which were in most ample supply and of highest food value.

DRUMMOND: That's interesting. I suppose a great number of people benefited, didn't they?

CRICK: The latest figures I have are a year old, but at that time in a single month over 3½ million people were put in a position to get nearly 10 million dollars' worth of additional farm products, chiefly fruit and vegetables, butter and eggs.

DRUMMOND: Well, of course, it's largely for you economists to make suggestions suitable for this country. What we nutrition experts worry about is: Can we count on a still further increased consumption in these vitally important protective foods by those who need them after the war? A vast improvement in national health will come right enough if we get the right foods to the right people, but how that's to be done is likely to be a big "headache" for the politicians and you economists. Of course, the farmer will come into the picture, too.

CRICK: He will, indeed. We've already agreed that there's no shortage of need. There are plenty of ill-fed people and many of them know they're ill-fed; but they haven't the means to improve their feeding. Then again, it's perfectly obvious that if we're to bring about a satisfactory standard of consumption in our own country and in the world at large there has got to be a big increase in certain branches of agricultural production. We're nowhere near over-production in the literal sense, either here or in America, or anywhere else.

DRUMMOND: No; I don't suppose we are.

CRICK: I believe somebody with a passion for arithmetic has estimated that for the whole world to secure freedom from want the total agricultural production would have to be nearly doubled, chiefly in dairy products, vegetables and fruit. The fact is that whatever we do to raise feeding standards on any broad scale, an increase in food production will be required. And yet we have this anomaly that in the period between the two wars there seemed to be too much food being produced, world stocks of agricultural commodities were increasing, and farmers all over the world were meeting incessant difficulty in trying to make ends meet.

Drummond: That simply means that the people who needed this food were just not getting it.

Crick: Exactly; and meanwhile, farming was terribly depressed. The importance of that fact is not limited to the farmer and his family. You see, although industrialization has made great advances all over the world, it still remains true that something like three-fifths of the world's people are directly dependent upon agriculture, so that you can't have a prosperous world without a prosperous agriculture.

Drummond: Very true.

Crick: Why, do you realize, Drummond, that at one stage in the early thirties, the wheat-grower in Manitoba had to give two bushels of wheat and more to pay for what he could have got for one bushel only three years earlier? How can we expect our factories to prosper when farmers throughout the world never know from year to year what their buying power is going to be?

Drummond: Well, it certainly looks to me, Crick, as though science is going to play a big part in solving these very human problems. I can look back on twenty-five years of scientific research on nutrition and see how our modern ideas have shaped. You, I imagine, can trace how economics has come to play so important a part in these discussions. There's one point I'd like to emphasize because so many people don't realize sufficiently how important it is. Many people imagine there's no room for improvement when they feel fairly well. They say —"Oh, yes, I have a little tummy trouble now and then," or "I get easily tired—but it's nothing—I really am very fit." They didn't realize they might be a lot fitter if they had better food. I recall a very wise remark made to me by Surgeon-General Parran, when I was in America last year. He likened malnutrition to an iceberg—only a tiny part is visible—by far the largest part of it is submerged and for that reason a hidden danger. That's very true.

CRICK: I like your iceberg analogy, because the other day I came across the results of a pre-war inquiry which seemed to show that, although there were something like eight million people in this country who couldn't afford a satisfactory diet, there was a far larger number that could afford to eat well but didn't. So a large amount of malnutrition results from unwise spending and ignorance of food values. It's up to you nutritionists to carry on with your process of education and it's up to us economists to find means for enabling all men, women and children to get hold of those products that are so necessary to health.

It won't be easy, of course. For instance, we shall need some pretty radical alterations in our methods of storage and distribution. When you were in New York a year ago, I've no doubt your sense of dietic fitness was gratified by the liberal supply of salads of every conceivable variety.

DRUMMOND: It certainly was!

CRICK: And I believe that was made possible in part by the regular delivery in New York of lettuces grown in Texas, 2,000 miles away. Those lettuces are transported not in open cars with the sun blazing down upon them and destroying their freshness, but in refrigerated wagons; they're pre-cooled before loading, and they're stored in refrigerated containers in the markets and shops. And yet, with all the capital cost of this modern equipment the stuff is there in New York at a price within the reach of most people's pockets. Shan't we have to do something similar here if we're to get more of these highly perishable foods on to people's plates in a health-giving and appetising condition?

DRUMMOND: Yes, a lot of our methods are hopelessly out of date.

CRICK: I suppose, too, it will involve a big increase in the drying of foods and refrigeration.

DRUMMOND: Yes, I'm certain of that, too. But may I go back to your point about education? I'm convinced that we've got to embark in the post-war years on a very extensive campaign for educating the public about food. I think you economists sometimes under-estimate the strength of habit and fashion and convention. People are very conservative in matters of food—why, it has taken a war to convince people (and I'm not sure they're convinced even now) that vegetables are not just a rather extravagant decoration for the real stuff of the meal—the meat and bread and potatoes. It's not easy to change the food habits, particularly of grown-ups and the danger is that when food becomes available again without all the paraphernalia of rationing, which, of course, may not be possible for some time after the end of the war, there may be a reversion to the old bad ways.

Crick: That raises the issue whether you are to rely on regimentation or education.

Drummond: Education every time; Hear, hear; I'd get at the young people. Begin at school to give them the foundations of simple knowledge about food and health.

Crick: Boys as well as girls?

Drummond: Certainly—boys as well as girls.

Crick: To which I'd add a knowledge of the principles of domestic budgeting.

Drummond: Yes, certainly. Another point on which most of us still want a lot of education is cooking. So many people seem to think that because nutrition experts talk about this, that and the other, it always is some kind of food fad. But actually, of course, really good cooking in the kitchen nearly always means that you get the best food value out of what you cook.

Crick: Well, that's where our housing experts come in, because it's constantly thrown up at me, and I'm sure at you, too, that you'll never get a sufficient improvement in nutritional habits until you get a radical improvement in kitchen equipment, and I think you yourself once remarked to me that every house ought to have a refrigerator. It's no use expecting a housewife to take trouble over the meals if she can't take pride in her kitchen. It's a matter of expanding and improving on the side of building, engineering, and the whole wide range of industries providing the machinery and plant and household equipment.

DRUMMOND: Yes, you're absolutely right there, Crick. In fact, it's one of our biggest difficulties at the present time trying to put across to the public advice about cooking when we know perfectly well that so many homes are so badly equipped. That's just got to be remedied. I imagine too we shall have to have very great changes in our marketing systems, especially for such things as vegetables, but that is much more a matter for you economists than for us biologists.

CRICK: I agree. We must aim at having the right stuff available in the right quality at the right price and in the right place.

DRUMMOND: Yes.

CRICK: Of course, this may mean, for a time at least, going short of some of the frills and fancies; but after all, cabbages should come before asparagus, and caviare must give place to—well, cod liver oil. As Beveridge says, we need "to put first things first, so as to ensure the abolition of want before the enjoyment of comforts." As to quality, I suppose that you, as a nutritionist, would wish to see a very considerable strengthening of the arrangements for protecting the consumer against unduly low standards and false criteria in food stuffs, and unhygienic conditions in places where food is handled?

DRUMMOND: Yes, I think we want a lot more done in that direction than has been done. The public should be given the fullest possible protection in regard to the quality of the food which it is offered.

CRICK: There again, Drummond, the most interesting thing about this conversation is that we keep on converging on very much the same point, namely, the necessity of acting directly upon the consumption end of the economic process.

DRUMMOND: You mean, by one method or another to make it possible for every family whatever its condition of life to obtain the foods that are absolutely essential to its health? You know, it has been said by someone, I think it was Rénè

Sand, that "health is purchasable." That's a terrible indictment of our times.

Crick: I agree with your ultimate objective but do let's keep our feet on the ground. I wouldn't for a moment understate what we can do in our own strength, but there are limits to the speed of our advance. I'm not thinking so much of the immediate post-war task of relieving starvation in Europe and elsewhere. That, after all—terrible as it is—is a short-term job: and we have been thinking in longer terms, although not so long as Wells' five hundred generations. You see, although the majority of the world's people are still dependent on agriculture, the proportion varies very widely indeed from place to place. In this country, it's exceptionally low. Great Britain is unique in the degree to which it relies on international trade and therefore it's essential that while we press forward with every possible line of improvement within our own borders, we should support at the same time every practicable measure of international co-operation to the same end. For example, if we are to have a healthy world trade we must, in collaboration with other nations, concert measures to remove what a member of Parliament recently called the pre-war "blight of unregulated surpluses."

Drummond: A blight it certainly was!

Crick: It is, of course, fantastic that those surpluses should be side by side with large-scale shortage and malnutrition. We were not using anything like our full capacity to produce and consume, and on all hands there was the horrid spectacle of "idle men and idle acres." Happily, there are many signs that all the world over men are seeing the necessity of putting their heads together to solve this life-and-death problem. If the Atlantic Charter is to become a real Magna Carta of mankind, you and I, Drummond, will agree that one of its first consequences will be the certainty of a good square meal for all—in a word, "freedom from want," or the guarantee of "daily bread."

III

"THE GOOD EARTH"

By Dr. W. G. Ogg, M.A., Ph.D.

Professor Drummond and Mr. Crick have told us about the food we eat and about what we need to keep us in good health. We seldom pause to think that every loaf, every pound of meat, and every glass of milk, in fact every stitch of clothing takes something from the soil. Besides this, vast quantities of plant food are washed out of the land every year by rain and carried by streams and ditches to the sea. This feeds the tiny plants and animals on which fish live, so even the fish of the sea get part of their living from the dry land. Can mother earth make good these losses and keep on providing us with food and clothing year after year without her supplies running short? She has been able to do so through many long ages for new soil is forming every day. Rain, sun, wind, and frost break down particles of rock; plants and animals die and decay; earthworms and other living things play their part and new soil is born—but the process is very gradual.

This was perhaps all very well a century or two ago when the population of the world was much smaller and when most of the food was actually consumed on the farms and in the neighbouring villages and went back on the land as manure, but to-day most of the food goes to great cities far from the farms, and the sewage is usually run into rivers or the sea, carrying with it much of the fertility of our fields. Modern sanitation is no doubt highly desirable, but it is robbing the land. We must make good the losses if we are to preserve the balance of nature and also grow the big crops needed to feed the present population of the world. And we must think of quality as well as quantity, for a poor or exhausted soil affects the food value of the crops which grow on it and this in turn affects our animals and ourselves.

We have learned how to repay our fields or we might have been faced with famine. Crops take a great number of different things from the soil, but the four principal ones are lime, nitrogen, phosphate and potash. All these substances are found in farmyard manure and this is excellent as far as it goes, for as well as feeding the soil it improves its texture and water-holding power, but there isn't nearly enough farmyard manure to go round.

Lime shouldn't be much of a problem—at any rate in this country—for we have abundance of chalk, limestone, shell sand, and marl, and the practice of liming the land is a very ancient one. But far too little has been used and most of our soil is crying out for it. In the present crisis the application of sufficient lime to the land would probably give a greater increase in food production than any other single measure, but unfortunately farmers cannot obtain adequate supplies. Transport difficulties may be partly to blame, but we could greatly improve the position by developing sources of lime more fully. The other week I saw waggons of ground limestone which had come all the way from Derbyshire—more than 350 miles—to sweeten the fields of Aberdeenshire, and yet some 50 miles from Aberdeen there are great deposits of high-grade limestone of which little use is being made.

Science has put at the farmer's disposal a whole range of so-called artificial manures to provide him with nitrogen, phosphate and potash. A source of nitrogen was found in the nitrate beds of Chile and another in sulphate of ammonia, a by-product from gas works, but very large amounts are needed and there would have been a shortage of nitrogenous manures had we not found a method of making them from the inexhaustible supplies of nitrogen in the air. The potash problem has been solved for many years to come by the discovery in several parts of the world of great deposits of potash salts—the relics of dried-up seas. We've also found sources of phosphate. For instance, bones—they are good as far as they go, but the supply is very small. A more important source is basic slag, a by-product of steel manufacture, but the greater part of our supplies come from phosphate rock. Huge amounts of the material have been found in North Africa, the United States, Russia and various other countries. It is mined or quarried, crushed to a fine powder, and either applied to the soil in this form, or treated with acid to make the manure called superphosphate which plants take up more readily.

Soils in many parts of the world fail to grow good crops because they are short of phosphate and as Mr. H. G. Wells pointed out a fortnight ago, these great deposits of phosphate rock are proving of inestimable value to mankind.

It is only about a century since artificial manures were first introduced, and it was much later before their use became general. An old farmer friend told me the other day that the productivity of his farm had doubled during his lifetime, and he attributed this largely to better manuring.

But that is not the whole story. As well as lime, nitrogen, potash, and phosphate, which they take up in fairly large quantities, plants need small traces of several other things. These are usually present in the soil, but not always. You have perhaps seen a crop of sugar beet with curious tufted tops. It was suffering from a disease called "crown rot" due to lack of a minute trace of a substance in the soil called boron.

Sometimes it is the animals that are affected and not the plants. For instance, sheep in some districts suffer from a disease known in this country as "pining" and in New Zealand as "bush sickness," because their pasture lacks cobalt, but the amount they need is infinitesimally small—less than one part in ten millions and a handful or two of a cobalt compound on an acre of land is enough to cure it. We have still a great deal to learn about these and other trace substances. Soils generally contain enough of them and too much may do as much harm as too little. You may have heard of a disease known as teart which affects cattle in parts of Somerset. It is caused by too much of a substance called molybdenum, but the quantity is merely a trace.

But our crops get some of their food in other ways. A healthy soil is not a mass of dead particles. It is very much alive, and contains besides earthworms and other creatures which can be seen, vast numbers of invisible living things. Some of these play a vital role in making the manures we have applied available to crops. Out of old dead plants they make food for new ones and some of them, for instance, the bacteria which form the little nodules or swellings you may have seen on the roots of clover plants, have the power of taking nitrogen from the air and greatly enriching the soil.

So far, I have been dealing with the feeding of our crops and the minute living things in the soil which help to make it fertile. Like ourselves, they need air and water as well as food. Waterlogged soils must be drained to let in the air and desert soil must be irrigated to provide water. Then we have cultivation. Primitive man, no doubt, found that it was necessary to till the soil in order to keep down weeds and provide a seed-bed for his crops. The first tillage implement may have been the branch of a tree and through the ages the plough was developed, first the wooden plough and then the iron plough and all the host of cultivation implements of to-day.

Now just a word about the many different kinds of soils and the reason for the differences. It is but natural that soils should differ when we consider the great variety of rocks that gave rise to them, and the different conditions under which they have formed. There are soils from hard, gritty rocks, soils from soft shales, soils from windborne dust, soils from the blanket of boulder clay laid down in the ice age and so on—an infinite variety.

But climate and vegetation also play a part—in fact the most important part—in settling what kind of soil will form. The same type of rock may produce what is known as a red earth in the tropics, and perhaps a black peaty moorland soil in Scotland—just because the climate is different.

Some types of soil such as the black earths of the Ukraine and the prairie soils of North America are very fertile, whilst in certain others the fertility has to be laboriously built up by the farmer.

Making use of his knowledge and experience, man has created some of the most fertile soils in the world. Through irrigation, for instance, he has transformed barren deserts into rich fields. The practice of irrigation is very ancient, for the early records of India and China and of the valleys of the Nile and Euphrates mention large irrigation works. In modern times we have the great Assouan Dam on the Nile, the irrigation projects of the Punjab and other provinces of India and many schemes in the United States, Australia, and other countries. There is now the vast total of over 200 million acres of irrigated land throughout the world.

But too much water is as bad as too little and in many places swamps have had to be drained and barriers built to keep out the sea. In recent years the Dutch have added a great tract of fertile land to their country by building a sea wall and reclaiming the Zuyder Zee.

We have plenty of instances nearer home, for the fertile fields of our British countryside were once very different from what they are to-day. In many places, forests had to be cut down, tree stumps and scrub torn out, stones removed and the land trenched. Throughout the dark ages the rich fenlands of East Anglia were swamps producing only fish and wildfowl, and at that time even the siltlands reclaimed by the Romans had been abandoned. It was not until 1631 that the Earl of Bedford and a company of thirteen co-adventurers, with the Dutch engineer Cornelius Vermuyden as adviser, undertook their drainage and produced some of the richest land in England. So you see our forbears, through hard labour, reshaped the land and bequeathed to us the pleasant countryside our farmers are cultivating to-day. And we must remember that they did this without the advantage of modern appliances and that this laborious task was done largely by hand or with the use of oxen.

> "The sire of gods and men with hard decrees
> Forbids our plenty to be bought with ease,
> And wills that mortal man inured to toil
> Should exercise with pains the grudging soil."

Until the outbreak of war there had been very little reclamation in this country for many years. From economic and other causes the trend has long been in the other direction—the less productive land reverting to its original state. Many farms on the margins of cultivation have been re-invaded by the scrub, heather, gorse, and bracken, from which they had been taken with such effort, neglected drains have again produced swamps and farm buildings fallen into ruin. In these marginal farms the struggle with nature has been going against us and our heritage has been shrinking. In the national interest we must face this problem. The land suitable for agriculture should again be renovated and steps taken to prevent more of it from reverting to waste. We have great areas of worthless moorland which could be improved and a few years ago the Macaulay Institute for Soil Research reclaimed two deep peat bogs at Carnwath in Lanarkshire. I must confess I was rather worried one day when the work was going on, to see our large tractor disappearing slowly in 20 feet of peat, but, in spite of difficulties, the scheme was very successful, and cattle now graze on excellent pasture on what was formerly a boggy waste of heather and cotton grass.

Since the outbreak of war the need for more food has stimulated land improvement in many parts of the country. For instance, Feltwell and some other fens in East Anglia which had become derelict have been cleared of scrub, re-drained and again made fertile. At the other extreme dry heaths which had been regarded as worthless and which had grown nothing within living memory have been reclaimed.

In the beginning of 1940 Massingham Heath in West Norfolk was 500 acres of bracken, gorse, and thorn trees and produced nothing but rabbits. The same autumn an enterprising farmer was harvesting crops from it, and when I saw it last year, it was carrying fine crops of wheat, oats, and barley.

From man's achievements let us turn for a moment to some of his mistakes. Lack of knowledge sometimes leads to disaster and some of the earth's most fertile regions have become barren wastes through mismanagement. Let me give you an instance.

In many parts of the world the rich surface soil has been washed away by water or blown away by wind leaving only bare rock or barren subsoil. This is known as soil erosion and it has already ruined millions of acres of land. It doesn't trouble us in this country, but I have seen it in America, Africa, and India.

The soil is swept away and cannot be replaced, but that is not all. When the porous surface soil which can absorb the rain has gone floods are apt to occur and huge gullies are carved out in the land which may affect the underground water and dry up the wells. The annual damage due to erosion in the United States alone has been estimated at 400 million dollars.

What causes it and how can it be checked? Usually it is due to unsuitable types of farming upsetting the balance of nature. In Canada it has been caused by growing wheat every year. This uses up the humus which binds the powdery soil together and the remedy is to keep up the supply of humus by practising mixed farming and keeping stock. In some parts of Australia a common cause of erosion is over-grazing. The grass is eaten down too far and the bare dry soil blown away.

We can prevent erosion on slopes by building the land into a series of flat terraces and another remedy is contour ploughing—that is ploughing round the slopes instead of up and down.

Erosion is one of the most serious agricultural problems in the world to-day. An exhausted soil can be restored to fertility by suitable manuring, but an eroded soil has gone for good or at any rate for many long ages until new soil forms.

Long before the days of organized science farmers had found that if they did certain things their crops grew better, but as a rule they did not know the reason. Modern science is trying to explain the whys and wherefores and this has led to fresh discoveries which in the last century have brought about vast increases in food production.

I have tried to give you some idea how we repay our fields for the food and clothing we take from them—how we obtain lime, nitrogen, phosphate, and potash from quarries, mines, and factories. We have learned that the soil is a living thing which must be understood and cared for. The engineer has provided us with an array of new implements to cultivate our land better and has shown us more efficient ways of draining the swamps and irrigating the deserts. Soil surveyors are mapping the distribution of the wide variety of soils which different rocks and climates produce, and we are learning the best ways of handling each type.

We have reclaimed fine land from barren wastes, but we have also through ignorance destroyed some of the richest land in the world. The scientific study of the soil is but in its infancy, and we have still many problems to solve. What is to be done for instance about the phosphate and potash which our cities are pouring into the sea and what is to be the policy with regard to our marginal and waste lands.

The good earth is our most precious possession, and in Britian its amount is small in relation to the population. In peace as well as in war we should recognize its value more fully and aim at understanding it so that we can use it to the best advantage and hand it down to our children better than we found it.

IV

RESHAPING PLANTS AND ANIMALS

By J. B. S. HALDANE, F.R.S.

WE live in a very artificial world, even in peace time. We are apt to think that this has only been so in the last few hundred years, since machines took over a lot of work which used to be done by men or animals. However, our domesticated animals and plants are not products of nature, but human products. A Jersey cow is as artificial as a cream separator, a bulldog is no more natural than a machine gun, a wheat plant is as much a human product as a loaf of bread. There are no wild animals or plants with their special qualities; and there never were.

Men can alter the qualities of animals and plants in two very different ways. The first way is by altering the conditions under which they live. You can fatten up a sheep by putting it on a good pasture, or improve the yield of a potato field by adding potash, phosphate, or some other constituent which is short in the soil. Even more striking effects are produced in other ways. To take two examples, a ewe, that is to say a female sheep, bears one or two lambs in spring. But till recently, many breeds never bore lambs at any other time. Professors Parkes and Hammond in this country have been able, by injecting a hormone from the pituitary gland of a horse, to give sheep two breeding seasons a year, so that lambs are born in autumn as well as spring. Two Soviet biologists called Zavadovski, Judovic, and their colleagues have got the same result. So has a biologist called August in Germany. This is going to be very important in increasing the numbers of sheep, both in Britain and in Europe, to their pre-war levels when the war is over.

Here is another example from plant breeding. In Britain we sow our wheat in autumn. The seeds germinate, but the seedlings do not begin to grow till spring. If the wheat is not sown till spring, it gets a late start, and does not give a good crop. But in many parts of the Soviet Union the frosts kill seedlings from wheat sown in autumn, and till recently special breeds of spring wheat had to be used. The yields were seldom as good as in this country. Then my fellow-member of the Moscow Academy of Sciences, Professor Lyssenko, had a great and simple idea. Why not give the wheat grains an English winter indoors? The wheat is stored dry in a granary. In January or February it is wetted, and the doors opened to give it a few degrees of frost. It is sown in March or April already germinated, and gets a flying start, so to say, so that it gives a good harvest. This process is called vernalization; it has made it possible to grow wheat hundreds of miles further north than was possible before. So Hitler's conquest of the wheat belt in the Ukraine has not cut down Soviet wheat production as much as he hoped. This has been a big factor in the Red Army's resistance. Some of you owe your lives to Lyssenko.

But such effects as these are not passed on from one generation to another. Wheat has to be vernalized afresh each spring. Ewes born in October instead of April do not usually bear lambs in October without a hormone injection. On the other hand, the differences between breeds are inherited. Some cattle breeds, such as the Aberdeen Angus, are primarily beef producers. Others, such as the Jersey, are primarily milk producers. Some apples, such as Beauty of Bath, ripen in August, others such as Lord Hindlip, not till February or March. These are examples of economically important characters. But other characters are also fixed in breeds. For examples Aberdeen Angus cattle are black, Jerseys usually brindled.

During the present century geneticists have discovered the laws according to which many characters are inherited, and also how new characters arise. The characteristics of a variety are handed down in two quite different ways. All domesticated animals, and many plants, for example wheat and peas, reproduce sexually, that is to say each plant or animal has a father as well as a mother, and named varieties breed fairly true. But

JERSEY COW WITH TRIPLETS

SEARCHING SHIP FOR DEAD RATS

some plants, for example potatoes, roses, and apples, are reproduced by cutting or grafting. All the millions of apple trees in the world called Bramley's Seedling are derived from one single tree grafted on to various roots, and are much more uniform than, say, greyhounds or Jersey cows. But they do not breed true from seed.

Novelties arise in three different ways. A new character may arise suddenly within a formerly pure-breeding strain by a process called mutation. Something goes wrong with the normal process of heredity, For example, two ordinary rabbits whose ancestors for many generations had had ordinary hair, unexpectedly produced young with shorter and softer hair than the normal. By breeding them together, a new variety called "Rex," like the Belgian fascists, was produced. Its skins are used for fur coats and collars. In the same way peas with soft, edible pods arose suddenly from the ordinary kind with hard pods.

Secondly, characters may be combined from two different varieties. For example, if we have a black rabbit with the soft Rex fur, and a white one with ordinary fur, we can combine these characters by crossing them. In this case the first generation of hybrids are neither white nor rex, but some of the second generation combine both characters. This method has been very extensively used in wheat breeding. For example, Saunders in Alberta used it to combine the frost-resistance of a Russian wheat with the high yield of an English one. It is sometimes possible to combine characters from two different species. In order to get potatoes which would grow in the Arctic, a Russian expedition was sent to Peru, the original home of the potato. They brought back a wild species growing near the snow-line in the Andes, but with very small tubers, and, by crossing, combined its frost-resistance with the high yield of ordinary potatoes. But it is usually much harder to cross species than varieties, and the combination of characters follows more complicated rules.

Thirdly, if we are dealing with a plant such as the apple, which is usually propagated by cutting, every seedling differs from the parent or parents. If you plant a thousand pips, most of them will not bear such good fruit as the parents, but one of the thousand may carry a lucky recombination of characters, and be worth growing. More than a hundred years ago, Mr. Cox, a brewer at Slough, grew a tree from a pip which bore the lovely scented apples called Cox's Orange Pippin. Cuttings from that tree are ripening their fruit in New Zealand and Australia to-day.

In practice the best breeds of domestic plants and animals have been built up by a very slow process. Only a few of their characteristics have arisen as units, and are inherited in a lump, for example, the hornless character of the Polled Angus cattle. Most of them have been built up in innumerable small steps. An experienced breeder will see points in a cow or a rose which you or I would miss completely. It takes years to get your eye in, and some farmers never do. A few men have a real genius in this direction, for example Bakewell, a Leicestershire farmer of the eighteenth century, who revolutionized our breeding methods both of cattle and sheep.

But not all the points of a breed are of economic value. I am not thinking only of fancy breeds of poultry, like the Silkie, with its white silky feathers, a crest of plumage instead of a comb, and a black face; but a poor layer. These fancy breeds are great fun, and of great scientific interest, but not of much use except for working out the laws of inheritance. I am thinking of the fact that a Jersey cow has to be of one colour, and a Holstein-Friesian of another, although race-horses, which are the most highly bred and highly tested of all animals, are of many colours. Perhaps our breeders have paid too much attention to inessentials.

For an example of scientific breeding I go to Denmark. The Danes established their butter industry by selection. Almost all the cows in a herd have calves, but only a few of the males are used as bulls. So a herd is improved most quickly by picking out the best bulls. But since a bull gives no milk it is not so simple to choose them. Danish breeders tested bulls by mating them to cows of known butter production, and seeing if the daughters did better than their mothers. The successful bulls, which they called butter bulls, were extensively used in their old age. The Soviet collective farmers go one better, and use artificial insemination, sending the semen, or seed, of a good bull, for hundreds of miles by aeroplane or carrier pigeon; so that a single bull might beget hundreds of calves in one season on cows whom he had never seen. We have taken up both these methods of stock improvement in Britain, but our farmers are not giving such a lead to the rest of the world to-day as they did in the eighteenth century.

The egg-yields of poultry and ducks have been stepped up by selective breeding until many birds have laid over three hundred eggs in a year. Selection is easier here, because you can get a great many chickens from one hen. But once again, the most rapid progress is made by selecting roosters on the basis of their mothers' and daughters' egg yield. Unfortunately, our best egg-producing strains of poultry are nothing like as healthy as our best dairy cows.

Similarly, sugar beets are selected on the bases of their sugar content, not their appearance. The analyst, who estimates sugar with an instrument called a polarimeter in the laboratory, is just as important as the actual breeder in this kind of work.

One reason why British breeders are not keeping up their former lead is that we have neglected the science of genetics, which deals with inheritance in plants and animals. Ten years ago there were two professors of this subject in England. Now there is none. But there are scores both in the United States and in the Soviet Union. Our first English professor of genetics, Punnett, invented the method of sex-linked crosses by which the sex of chicks can be determined at hatching. Before the war several million chicks were reared from such crosses every year. So Professor Punnett's salary was not a bad investment for his country.

I hope that as part of our post-war reconstruction we shall give genetics a serious place in our research and education.

The geneticist cannot do a very great deal for British agriculture. Our plants and animals are pretty good. His biggest tasks will be to improve the health of our high-laying poultry, which are delicate birds though their high egg production is no more unnatural than high milk yield in cows, and to do for meadow grasses what past generations have done for wheat and barley.

Another field for the breeder is the improvement of fur-bearing animals such as the fox and rabbit. New colour varieties of the fox always fetch a high price, but are not likely to be valuable when they become common. What we need is improvement in the durability of furs so that a rabbit coat will last as long as a musquash. In view of the changes which have been produced in Angora rabbits bred for their wool, this does not seem impossible. The Swedes are already beginning the selective breeding of timber trees. We should do the same.

An almost untouched problem is the breeding of single-celled plants such as yeasts, bacteria, and moulds, which carry out fermentations yielding various chemicals such as the ethyl alcohol in beer, wine, and spirits, and butyl alcohol, which is used in the manufacture of explosives. Different breweries have their own races of yeast, but the hybridization of yeasts, so as to combine valuable qualities, was only accomplished just before the war by Winge in Copenhagen. Breeding of these microscopic plants would help many branches of the chemical industry.

But Britain is the centre of the great Commonwealth, and in many parts of it, especially India, the animals and plants are as far from perfection as were our own in the middle ages. The self-governing Dominions are tackling their own problems, and British geneticists are improving a few tropical plants such as cotton and bananas. But the centre of the world's research on tropical agriculture was in Java. Dutch scientists have been particularly successful with the sugar cane. No one can tell how much will be left of their research institutes when the Japanese are cleared out. We need teaching institutes in Britain where students can come from India, West Africa, Jamaica, and so on, and research institutes in the tropics where they can study their own problems at first hand. But I must apologise. Mr. Wells has told you that the doctrines of the political party to which I belong are fifty years out of date.[1] You may think that my suggestions are Victorian.

I want to leave you with the conviction that the animal or plant breeder is a truly creative man or woman. I am thinking particularly of men like Keens, the Isleworth market gardener, who made the first modern strawberry in 1806 by crossing a big purple species from Chile with the small red European species. Someone will say that breeders merely pick out what they want from the materials provided by nature. You might as well say that a sculptor merely chipped away marble from a block, and the statue was there all the time. I want you to be proud of the great achievements of our breeders in the past, proud that Denmark was colonized by Large and Middle White pigs from England which used to provide so much of our bacon, proud that English rams are being used to improve wool production on the giant Soviet sheep farms. And I want you to see that when the war is over, British men and women will have the opportunity to carry on their great traditions by making still more beautiful and useful animals and plants.

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[1] And, by the way, I am not a doctor as he stated.

V

THE BATTLE OF FOOD

By JAMES FISHER *and* J. W. MUNRO

JAMES FISHER: Both of us are members of teams investigating pests—animals that compete with man. You are concerned with the tiny pests called insects and I with the larger and more obvious pests called rats. I don't know whether people realize that man is only now learning to control the vermin which eat a large proportion of the food he so painfully wins from the soil.

J. W. MUNRO: Both of us are continually asked very much the same sort of questions, "How much damage," people say, "do these pests do?" I might tell you that the grain-weevil destroys half-a-million pounds of grain annually and nobody could contradict me because no one is in a position to refute my guess.

FISHER: In the same way I might tell you that rats in Britain do twelve or twenty or forty or a hundred or even two hundred and fifty million pounds' worth of damage every year. All those figures have been given in public during the last year. I haven't an idea which of them is near the truth. All we can say is that rat damage amounts to millions.

MUNRO: Yes, we neither of us like these estimates and one reason is that as workers on the job our problems are serious enough. Let me begin by asking you, as a scientist, Fisher, what are your major problems. You deal with ships and ports and warehouses, don't you?

FISHER: I should explain that there are two species of rats infesting Britain. The black rat, as it is generally called—though it is not always black—has been with us possibly since the time of the Crusades, and it was introduced possibly by the Crusaders' ships. In the early eighteenth century, probably about 1728, a new rat, the brown rat, came from Russia and spread through

Britain pretty quickly. The old black rat gradually gave way to the new brown rat in the country districts, from which it has now practically disappeared. But it did hang on in the towns, particularly in the seaport towns. In many of the big ports the black rat is still the dominant rat or at all events on equal terms with the brown rat. It can climb much better than the brown rat, and so it can live more easily than the brown rat in warehouses of several stories, in all sorts of high buildings, office buildings, cinemas, theatres, and places like that where it pays rats to climb. Another thing is that when the brown rat infestation became bad, the human race started to make its buildings rat-proof at ground level with concrete and wire, but it forgot about the black rat and did not make them rat-proof above the ground. And the black rat, the climber, can still get in above the ground. I won't say that the black rat has been staging a "come-back," but I would say that it is still dominant in some port areas and its populations are being kept up by new arrivals replenished from ships. And, of course, to-day as always, it is by far the commonest ship-rat. In most big ports, for instance, there are between three and four black rats killed on land to every brown rat. And about nine hundred and ninety-nine black rats on ships to one brown.

MUNRO: Are you more concerned about the black rat as a destroyer of food or as a carrier of plague?

FISHER: Well, to be quite definite, more as a destroyer of food. The most careful watch is being kept on the black rat in this country and on black rats on ships to see that none of them carries plague. Each ship is inspected as it comes to the port, rats taken off and those rats examined for plague. The routine is so cut and dried that, though there have been no cases of plague rats for some years, as soon as the discovery is made in the laboratory a couple of telephone calls are put through and people are at the scene of the crime immediately. They can go to the right wharf and the right ship and have the situation in hand.

MUNRO: Now that comes round to my side of zoology, namely, that the spread of plague depends on the rat having fleas or some other parasite. From what you have said, Fisher, it is not as a plague-carrier so much as a destroyer of food that the black rat is our enemy. How is the rat war going? What progress are you making?

Fisher: There are four kinds of rat-destroyers: first, local authorities, who, through their sanitary inspectors in town districts or through pest officers of war agricultural committees, have done excellent work in certain areas; second, large service companies working on a big scale at jobs like fumigation, rat poisoning, or rat trapping; third, the small men, and fourth, the people in direct labour schemes. But it is not often possible to take over a whole block of different factories, offices and so on, adjoining each other. And only by doing this can one get a rat population under control, rather than just the rats in a particular building. Up to the war there was no means of compelling people in a large block—different interests, different firms, warehouses, houses, factories—to get together and have some mutual system of rat-control. But now, of course, things are altered, and it's possible to get that kind of job done. As for the small private people, the one-man-and-a-dog affairs, they have done very good work in the past, but they have never been able to tackle big jobs and really get at the rat population of a substantial area.

In the direct labour schemes, local authorities, port health authorities or country war agricultural executive committees have taken over a whole area deliberately and done their own direct rodent control. And the new schemes have been extremely successful. How about block control in the case of insect pests, Munro?

Munro: Block control is undoubtedly a thing to aim at. But it does present serious difficulties. But one problem that worries us is this: insects coming in from ships may not settle down in the ports at which they arrive; the goods they infest may have been shifted elsewhere and the insects turn up far from the port at which they arrive and it is extremely difficult to keep track of them. When rats arrive and threaten to settle in a district you can tackle the problem almost straight away. With insects it is different. Their movements often cannot be traced. Infestation, as we call it, is not so easily spotted and that is one of our biggest difficulties.

FISHER: One of your main jobs is intelligence, keeping maps and filing information. Of course, that's important to us, too.

MUNRO: Then there is a point that deserves mention. I am not sure in your case how far the black rat or the brown rat populations would keep up their numbers if you could completely stop new arrivals from abroad. I take it that the brown rat is so well established that it carries on independently of fresh arrivals. But what about the black rat? Is it sufficiently established to carry on independently?

FISHER: Certain populations of black rats are quite self-supporting and self-contained, but if all goes well, we should be able to get at every one of them in the next few years. Once the ports get down to their black rat problem, they will reach the stage where it is almost an interesting event to have a re-infestation.

MUNRO: Why I ask, Fisher, is because with my pests too—the insects—there are those that will and can carry on independently of further arrivals, and those which in the absence of fresh arrivals will die out. Obviously, the important thing is to tackle those which are independent of fresh arrivals. For example, there's a little beetle which comes mainly from Australia, and also from India, which only continues to exist in this country because its numbers are constantly being replenished from those places. If we could deal with ships and ensure that no insects came into this country from ships, these beetles would die out. On the other hand, there are some insects, which originally came probably from the Eastern Mediterranean or even further east, which now seem to have acclimatised themselves in this country, and are carrying on independently. Probably the most important of these is the cocoa-moth; when I use the word "cocoa-moth" I have to be careful because while it is very prevalent in cocoa, the cocoa and confectionery trades resent very much the term "cocoa-moth." They think it implies a slur on them; and it is true that the cocoa-moth attacks many other things besides cocoa—tobacco, and other vital commodities.

Fisher: I suppose this problem is being tackled.

Munro: It is being tackled—very strenuously.

Fisher: So you think control in food stores is pretty good.

Munro: Yes, and that brings us to the other side of the problem—food growing. It's an admitted fact that the extension of wheat-growing or the growing of other grain, such as oats, is limited by those insects which the farmers call the wire-worm. Farmers have in fact been advised that where the number of wire-worms occurring in the soil exceeds six-hundred-thousand an acre, they would be well advised not to attempt to grow wheat. But Fisher, when the farmer has overcome his wire-worm troubles and harvested his grain, how far is he likely to have rat trouble in his corn-stacks?

Fisher: I don't suppose there's a country parish anywhere in Britain where there are corn-stacks with no brown rats in them. Sometimes there are three or four hundred rats living in a stack. You can see what a very serious menace this is. Three hundred rats in a stack are roughly equivalent to an animal as big as a middle-sized bear, living in the stack and eating the corn. A government order now compels people to surround each stack at threshing-time with wire-netting and to kill the rats and mice as they come out of the stack. Most county war agricultural executive committees have a staff of operators working under the county pests officer, and they are prepared to keep farms free from rats—and for that matter rabbits—for a moderate charge.

Munro: Yes, very interesting. Now the rat doesn't merely take corn in the stack—what about your potato clamps?

Fisher: The country rat can be a serious pest with roots and potatoes in clamps. Rats sometimes make quite small holes in potato clamps, and roll potatoes out through them. I know a case where a whole barrow-load was rolled out. It is not so much what the rats eat or roll out—the frost gets in and does more damage to the potatoes than even the rats.

MUNRO: And what's more, an insect restricts our growing of potatoes because it carries virus disease which is the worst enemy of the potato-grower south of the river Tweed. So there you have two insects—wire-worm and the potato-virus-carrying insect—which do determine in quite a large measure the extent to which we can increase our production of wheat and potatoes. Haven't you, too, among your higher animals, another which restricts crop-production?

FISHER: Yes. The wood pigeon—a very interesting creature. It's really the only native bird which is entirely injurious to man. It's not like the rook which is still the subject of debate. It's a hundred per cent bad, the wood pigeon. It's a pretty wide-spread bird, and, so far, we have not been able to control it. At present the British Trust for Ornithology is working hard to find out about its habits and doing research on control methods.

MUNRO: In fact you don't know enough about the wood pigeon to achieve control?

FISHER: Not yet. We are trying to get as many people as we can to observe wood pigeons and send in their observations. We are asking about feeding habits and flocking habits. We are asking people to fill in cards giving details of wood pigeons' nests they have observed and the things that happen in those nests. In this way we are trying to get the picture of the wood pigeon's life.

MUNRO: If I am rightly informed, you have had, or rather the country has had, in this work, considerable help from the county war agricultural committees.

FISHER: I can't overstress how very useful they have been.

MUNRO: Don't you think that really the crux of all this that you and I and others are trying to do, lies in this: that unless we can combine—as we are doing now—research into the life habits of animals, with the proper administration of such measures as we may be able to propose or recommend, we really are going to fail in our task? Isn't it really essential that the administrators and research workers should have a real understanding of one another's problems?

FISHER: I can't tell you how much I agree with you, Munro. I think both sides are rapidly losing some rather awkward opinions they have had. The scientists have had the notion that their research has got to be academic and long-term; and the administrators—to put it bluntly—sometimes have not had much use for scientists, either because they have thought that the scientists lived in a world of their own, or because they have regarded them merely technical advisers, who should be allowed out of the back rooms for occasional consultation.

MUNRO: What it really amounts to is this, we have got to have somewhere an interpreter standing between the research worker and the administrator—one who is synpathetic with both their aims and has understanding of both their difficulties.

FISHER: The research interpreters that you mentioned do, as we both very well know, exist in the form of the three Research Councils—the Agricultural, Industrial and Medical.

MUNRO: Yes, Fisher, but does the public know that? Wouldn't you agree that the public, even if it knows that the Agricultural Research Council, the Industrial Research Council and the Medical Research Council do exist, doesn't know their potentialities?

FISHER: Yes, it's a matter of knowing which button to press and people don't know how many buttons there are already sitting on the wall waiting to be pressed.

VI

PRESERVATION OF FOOD

By Sir Edward Appleton, F.R.S.

Air, water, food—these are our three primary needs. Without air, a man dies in a few minutes; without water, in a few days; without food, in a few weeks.

Food is first and foremost the fuel that heats our bodies and gives us the energy we need. We measure the fuel value of food in calories, just as we measure the fuel value of gas in therms! and the number of calories we need depends on our job. The fighting soldier, the miner and all doing heavy physical work need a great many more calories a day than does, say, the office worker.

Now the food that gives the most calories for its weight is fat. There are about 200 calories in an ounce of butter. Thus, even if a soldier could live entirely on butter, which he couldn't, it would take well over a pound a day to produce the calories he needs. And if he lived entirely on rice, he would have to get through about 2½ lb., and when that amount is cooked it's a very big helping. The idea that a Japanese soldier can manage on a mere handful of rice a day is simply plain nonsense. He needs every bit as much food as our own soldiers. If he didn't get the calories, he couldn't do the work. The idea that we could have foods so concentrated that all we should need would be two or three tablets a day is even more nonsensical. But it's amazing how widespread is that fallacy.. Anyway, who wants to live on two or three tablets a day? I rather enjoy my meals and I expect you do too.

But food is not merely fuel. It must also provide all the things that are required to build up the bones, muscles, nerves and brain and the rest of the body, and to keep them in good repair and working order. It must therefore be right, not only in quantity, but also in quality.

So you see that food is a very real munition of war, even more vital than aeroplanes, tanks and guns, because the fitness of the men and women who make them, and fight with them, depends on their getting food of the right quantity and quality. This is especially true for us, because in peace-time we produced here at home only little more than one-third of the food we needed. We know how near the U-boats brought us to starvation in the last war. The achievement of our farmers in increasing the quantity of food we now grow for ourselves to about two-thirds—that is, nearly doubling it—is a tremendously important one.

Fed so well as we are to-day in such difficult circumstances, it is hard for us to believe that less than fifty years ago people were apprehensive lest the world should not be able to produce enough food for its population. It was in 1898—the first year of the Boer War—that the President of the British Association uttered a solemn warning. His actual words were "England and all civilized nations stand in deadly peril of not having enough to eat." Now we need have no fear on that score. Sir John Russell, the Director of the famous Rothamsted Agricultural Research Station, has assured us that, thanks to the advances made in science and invention, the world can produce all the food that mankind is ever likely to need, though, as Mr. Crick said in the second talk in this series, the world is at present producing only about half of the food that is needed for complete freedom from want. What we have to think about instead is, as Sir John points out, where that food shall be produced, at home or overseas. That is one of the really big questions of post-war reconstruction for us.

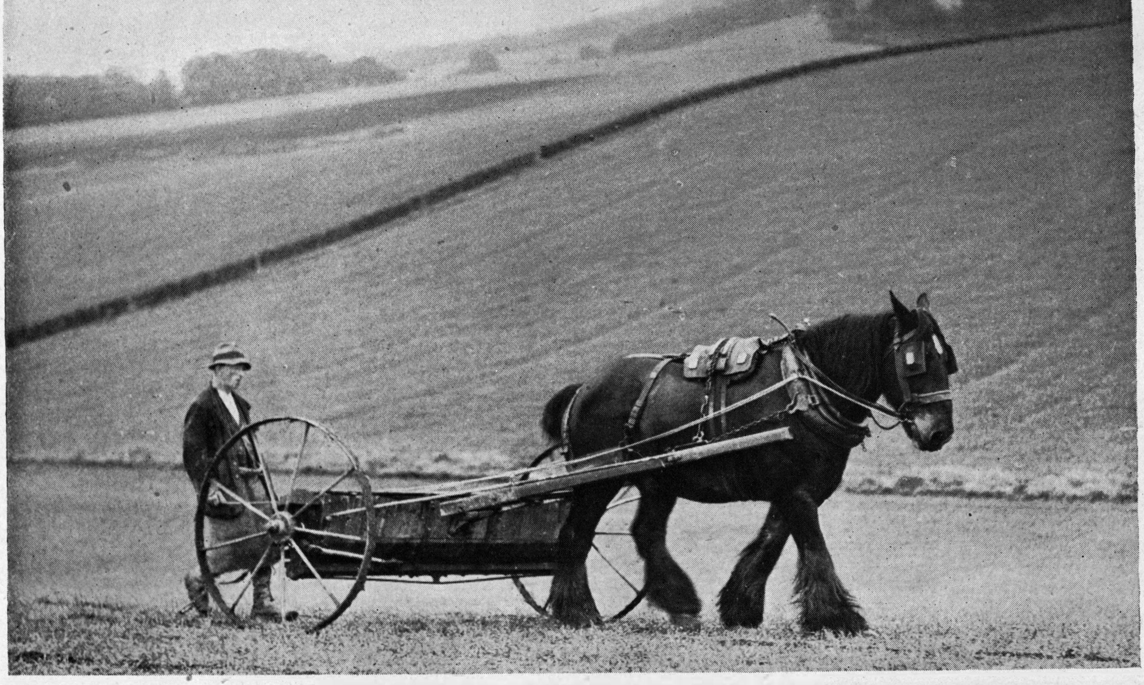
There was a big assumption in Sir John Russell's question—where shall the food be produced, at home or overseas. Did you notice that he assumed that, even if our food were grown at the other end of the earth, it would still reach us in first-rate condition. He was quite right to do so, for there have been just as big, perhaps even bigger, advances recently in the transport and storage of food, as in its production. Some foodstuffs, like wheat, rice and sugar, are easy to store, but most of them are very perishable. We all know that, in the natural state, milk will keep fresh for only a day or so, meat and fish for a few days, and fruit and vegetables for periods from a few days to a few weeks. Have you ever realized why the spices were so much used in the Middle Ages? One reason was that the meat sold in the cities, even though it was produced at home, was so offensive that spices and other strongly-flavoured things like onions and garlic had to be used to mask the taint. The only way meat and fish could then be preserved was by salting and smoking; green vegetables, like cabbage, could be pickled. Nowadays we get excellent meat from Australia and New Zealand after a voyage of 12,000 to 14,000 miles; and even highly perishable fruit like peaches and plums from South Africa, 6,000 miles away. It was, of course, the invention of mechanical refrigeration about a century ago that made it possible to import perishable foodstuffs like these from the other side of the world. The physicists and the engineers did that. But that was only the beginning, and the biologists have had the much more difficult task of finding out the proper temperatures and other conditions that must be maintained in the ship's hold (or in the cold store; for transport, after all, is only storage on the move) to keep the various commodities in prime condition.

The other great modern method of preserving food is canning, and it was invented about one hundred and fifty years ago. There is one broad general difference between cold storage and canning. Cold storage preserves things in their original condition—we compare frozen lamb with fresh lamb and cold-store apples with fresh ones. But canned foods are altered in the process, which is really a sort of cooking. Corned beef and canned peaches are both attractive foods, but they are quite different from the fresh articles. Thanks to the researches of the biologists and other scientists, the nutritive value of food can be excellently preserved, both by cold-storage and by canning.

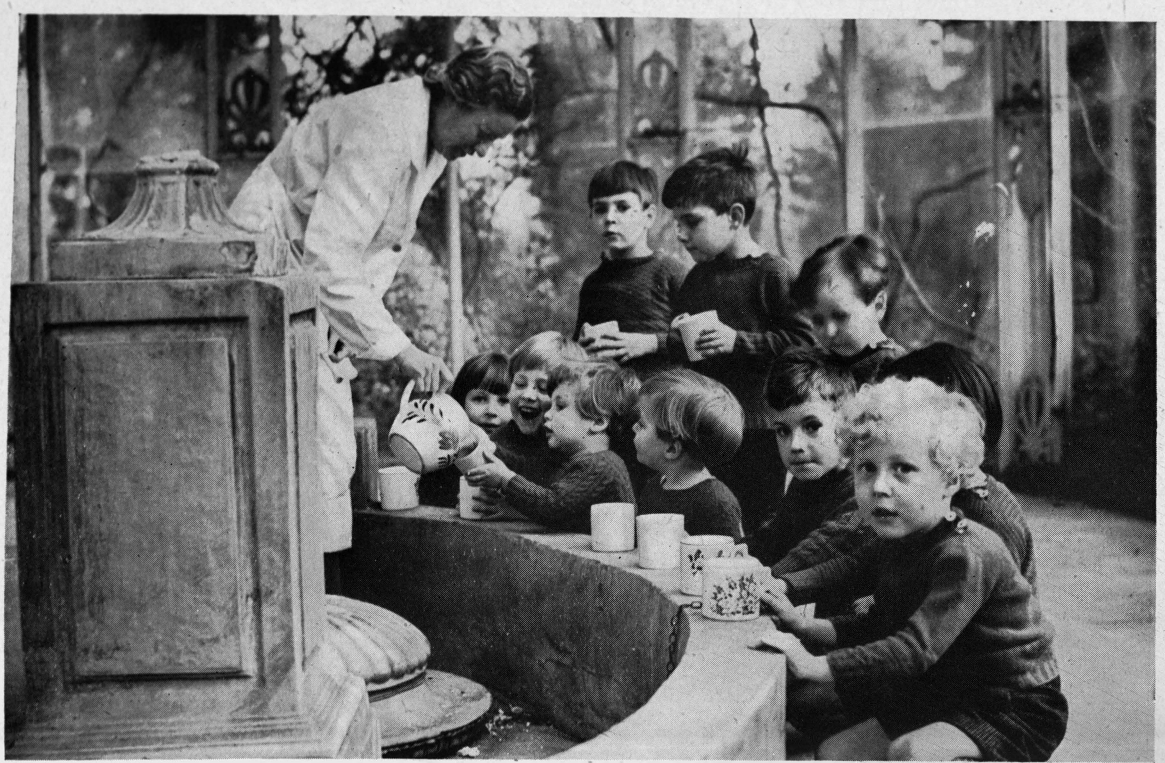
Recently, as I expect you've read in the newspapers and heard over the wireless, another method of preservation has been developed. I mean drying or dehydration as many people prefer to call it. Dried milk has been on the market for a number of years, and we are now all familiar with the dried egg that the United States is sending us, and which makes such excellent omelettes and scrambled egg. To-day, thanks to biological research, in which I'm glad to be able to say we in this country have been playing a leading part, not only milk and eggs, but also meat, fish and vegetables can be dried so efficiently that their nutritive value is fully preserved, while their appearance and flavour when they are reconstituted with water, are such as to make them virtually indistinguishable from the normal foodstuffs.

Dried foods must be carefully packed to keep out the air, because of the moisture and oxygen that it contains. When this is done, they can be kept for long periods at ordinary temperature and don't need expensive cold storage. There is, however, one limitation about them that I ought to mention. You cannot dry large pieces of food, and so meat and fish must be minced and vegetables sliced. There is, however, a special type of drying being developed by which it is possible to dry such things as steaks and other relatively small pieces.

But these dried foods have a special characteristic that is of enormous importance in war-time, when savings in transport are essential for both military and civilian purposes. I don't know what your weight is, but say it is ten stones. In that case about six stones of you is water, just plain ordinary water. Meat contains the same amount of water as you do, that is about 50 per cent, and green vegetables as much as 90 per cent. You can see how enormously the weight of food is reduced if we take nearly all the water out of it, as we do in drying. A ton of dried meat contains three times as much food as a ton of carcase meat; and a ton of dried cabbage ten times as much as a ton of fresh. Drying also reduces the volume of food as well as its weight, but here the greatest gain is got by compressing the food after you have dried it. By doing this we can pack into a ship's hold five times as much dried meat as carcase



SPREADING PHOSPHATES ON ICKNIELD WAY



MILK SERVED TO CHILDREN

meat, and it doesn't need to be refrigerated. No less than thirty times as much dried cabbage as fresh cabbage can be packed into the same space. It is an amazing sight to see a small green slab, two and a half inches across and half an inch thick, thrown into boiling water and in a few minutes have enough good boiled cabbage for half a dozen people. I'm convinced that we shall see great developments in the drying of food when peace returns, and I'm sure you will agree with me when you think over the possibilities. Do you know how much water we imported in our food in peace-time? About three million tons a year. That is equivalent to a large cargo ship arriving at our ports every day.

So far I've been talking mainly about imported food, and about the shipping space we can save, especially during the war, by reducing volume by drying. But you'll see at once that any way of treating food to make it keep better, or to make it easier to move about, can, if we wish, be applied to food that we produce in this country. We do a good deal of this already. I'm sure that many of you have taken an active part in jam making during the war, and by so doing have helped to make the fruit that ripens during a few weeks available for eating in another form all the year round. One of the characteristics of our natural food supplies is that they are not produced continuously and at a steady rate. Most of them are subject to seasonal influences. They are plentiful at one time, but absent or in short supply at another. It is clear that the more we can improve out methods of treatment and storage, the better able we shall be to preserve any surplus of a particular food when it is abundant, so that it will be available for us to eat at any later time we choose.

Now I want to talk to you for a few minutes about the future, and the sort of thing that we shall be able to do if we want to. I say "want to", because while the scientists and technicians can show us what can be done, it is for us who buy and eat the food, and especially our wives who get our meals, to decide what *shall* be done.

There are two broad trends in the progress I've briefly described. The first is to take perishable food like meat, vegetables and fruit, and to treat them in such a way that they become relatively imperishable. The three main methods of doing this are cold storage, canning and now drying. Each of these methods has its special advantages, and I don't doubt that all three will, in the future, be increasingly applied to the world's food supply.

The second trend is to take the preparation of food out of the kitchen, and move it back towards the farm and market-garden. For housewives who prepare their families' meals themselves, and they've always been the vast majority, this is a great boon. It is also a great boon to canteens and other places where large numbers have to be catered for, and I'm sure it's a movement that will grow rapidly. But this second trend has other advantages. It means that food can be prepared without the delays of passage through market and shop, so that it's absolutely fresh and in prime condition. It also means that all the inedible parts can be made into animal food and other by-products without the waste of effort involved in carting them about the country, after which, in peace-time at any rate, they generally end up in the dust-bin! For instance, the frozen beef we import now has the bones taken out of it before it is shipped. That saves a good third of the shipping. The bones can be made into glue and other valuable products on the spot, and these products can then be shipped separately if required; and of course they don't need precious refrigerated space as the meat itself does. If we liked, we could go on doing that in peace-time for the beef we want for roasting and stewing. In fact we could go further, as is being done already on a quite considerable scale in the U.S.A., and have the beef exported ready cut into steaks, joints, etc., just as the housewife wants them. With the beef we want for mincing, we could go still further, and import it as dried mince that could be kept in the store-cupboard till wanted.

We're all pretty familiar with what can be accomplished along these lines by refrigeration and canning, and so I want to end by saying a few words about the possibilities of drying. I've already mentioned dried meat and dried cabbage, so I'll take potatoes and milk as examples.

Potatoes are an important article of diet, and are rather troublesome things for the housewife to prepare and cook. What can drying do to help her? She could have dried potato in the form of strips or slices, which, after reconstitution with water, can be boiled or fried in a few minutes. If she's not time to do even that, she could have a potato powder that would merely want stirring with boiling water to make mashed potato indistinguishable from ordinary mashed potato. You couldn't have anything simpler than that, could you?

As for milk, we're all glad to have the household dried milk Lord Woolton provides for us. It is a valuable food, but it is skimmed milk, and so not the same thing as ordinary milk, and it takes a few minutes and warm water to prepare it. But there's a dried milk that merely requires stirring into cold water to give us milk that is indistinguishable from the ordinary pasteurized milk we drink every day. This is spray-dried full-cream milk, and when properly packed it will keep for a year or more. So if we should prefer to buy our milk, say, once a week, and to make it up, which only takes a moment, when we actually want it, it could be done, and of course the cost of distribution would be much less than that of liquid milk. If we didn't want to do that, we could at least dry the surplus of milk that must be produced in the summer if the winter supply is to be adequate and use it to even out supplies throughout the year.

I have tried to put before you briefly a few of the ways in which the handling of food has developed and is still developing, so that you, as the consumers, may consider which of them may meet your needs. I suggest that the main questions you'll have to settle are: First, do you want the preparation of your food to be increasingly done before it reaches you? If it is you will be relieved of the drudgery of it and, moreover, the raw materials will be handled more economically. Secondly, do you want those foods, when you buy them, to have been so prepared that they can be kept in larder and store-cupboard without deterioration in nutritive value and in attractiveness?

We often treat our meals more as a necessity than as a pleasure, and are inclined to regard cooking as what the Army calls a "fatigue" rather than as an art. If we're to get the full nutritive value out of our food, it must be attractive and enjoyable. That is a simple fact of physiology. In short, food should not be merely fodder! it should also be fun. Now, would relieving the housewife of much of its preparation help towards that end? I'm pretty certain it would.

VII

THE CONQUEST OF THE GERM

By L. J. WITTS, M.D., F.R.C.S.

I WONDER what pictures come into your mind when you hear the word germ. Creepy things with suckers and stings? Gargles and disinfectant smells? I think of the meningococcus, the germ of spotted fever. At the height of an epidemic, when it is flushed with victory, the meningococcus can kill a strong man in twelve hours. Spotted fever killed two thousand young British soldiers in the last war. Or it may produce a lingering illness which leaves a child deaf and dumb and crippled. To-day the meningococcus has lost its sting. It is no longer allowed to kill or cripple. The new sulphonamide drugs have put an end to all that. A boy comes into hospital, feverish and fretful. The meningococcus is streaming through the channels of his central nervous system. We treat him with these new drugs and in twenty-four to forty-eight hours that boy may be sitting up in bed, turning over the pages of a book. That is the miracle of the twentieth century. Let me tell you about it quite simply.

First of all, what are germs? They are microbes, and you know what a microbe is because you remember Belloc's poem:

The microbe is so very small
You cannot make him out at all,
But many sanguine people hope
To see him through a microscope.

It was a Dutchman called Leeuwenhoek who saw them first with a primitive microscope in the year 1675. He found what he called "little animals" in some rain water which had stood in an earthen pot. Nine years later he discovered even smaller germs, which we now call bacteria. Microscopes have gone on improving since Leeuwenhoek, till to-day we have the electron microscope that works on the same principle as television. It works like this: powerful electro-magnets focus a beam of electrons in a vacuum, it lets you see and reveal the ultimate limits of living matter—molecules even. The electron microscope can magnify 100,000 times and it shows details undreamed of before by anyone save the poet. We can see something very like the

> Seven tufted tails with lots
> Of lovely pink and purple spots
> On each of which a pattern stands
> Composed of forty separate bands.

For these photomicrographs do actually show us characteristic tails and bands in things too small to be seen by ordinary light, the five black spots on the virus of cow-pox, and so forth. So now we recognize three kinds of microbes, the large size or little animals, the middle size or bacteria, and the smallest size or viruses. Only a small proportion of these microbes are harmful. There are good microbes as well as bad microbes. In fact this would be in very truth a sterile world without microbes. The baby takes in microbes with its first breath and its first food. We have some reason to believe that it could not thrive without some of these microbes, which help it to manufacture one of the vitamins necessary for survival.

A germ, then, is a microbe which produces disease. Remember the names of Pasteur, Koch and Lister who discovered that. Some people are so revolted by the very idea of germs invading and multiplying in the body that they just refuse to believe in them. They maintain that if we ate healthy natural foods we shouldn't get diseases. Now, it's true that good food is a very important weapon in the conquest of the germ, but it's not the whole story. In fact some germs, such as the virus of infantile paralysis, seem to prefer to attack the best-nourished and best-cared-for children.

The pioneers taught us two other methods of fighting germs. One is to keep germs away by good hygiene, pure water, pasteurized milk, and so forth. We teach that coughs and sneezes spread diseases, and we segregate women like Typhoid Mary who gave typhoid fever to all the families she cooked for. The other method is inoculation—getting the body to learn to fight germs. The most important example of that in our country is inoculation against diptheria. If we give the toddlers a minute dose or two of the poison of the diphtheria germ, theylearn to destroyit. Then they are less likely to have a bad attack of diphtheria when they begin to mix with other children. These three methods—food, hygiene and inoculation—are purely defensive and we all know now that defence doesn't win a war. We've taken the offensive. We're conquering the germ to-day by actually killing it when it invades the body. That's a pretty tall order, to kill the germ without hurting the patient.

As often happens, the big fellows were the first to give in. These large germs, or little animals, cause, in the main, tropical diseases like malaria. Mankind had learned to cure malaria before scientists had discovered the malaria parasite or germ. In South America the natives of Peru and Bolivia had found that the bark of the cinchona tree was good for malaria. When the Spaniards conquered Peru, the Jesuits brought the Peruvian bark to Europe. And in the fullness of time we learned that it is the quinine in the cinchona bark which kills the malaria germ without hurting the patient. So the thing could be done. But how to do it again for other diseases?

That was the discovery of the great scientist Ehrlich. Ehrlich was a German Jew. All his life he was fascinated by the action of coloured dyes. Why one tissue will take up one dye very strongly and not another. Ehrlich argued that it should be possible to discover poisonous colours or dyes which had a special affinity for the germ and did not touch the host, i.e. patient. Or he thought of the seaweed, which concentrates in its substance the iodine which is present in infinite dilution in the sea. And he argued that it should be possible to make drugs which could be given to the patient and would circulate in the blood stream as the iodine circulates in the sea. They would be so dilute that they would not hurt the host, i.e. the patient, but they would be concentrated in lethal strength in the substance of the germ. Ehrlich succeeded in both these tasks. He found those dyes and near the end of his life, in 1910, he produced 606 or Salvarsan. Salvarsan contains arsenic in such a form that it is concentrated on the germ without damaging the patient. Salvarsan was important enough in itself because it cures syphilis and a number of other diseases. But more than that, Salvarsan marks an epoch, an epoch as momentous as the first aeroplane to fly. Arsenic, antimony, bismuth, mercury, all could be applied in the same way, and a great number of remedies was discovered, particularly for tropical diseases. The power of the little animals was shattered and mankind entered into possession of the first of the three kingdoms.

But oddly enough these drugs which killed the little animals or protozoa, wouldn't work against the bacteria and the viruses. The bacteria refused to be stained by the dyes. They refused to concentrate the poisons in their little systems. For a whole generation the remaining two kingdoms of germs resisted man's attack. This was very disappointing, because these germs are responsible for most of the diseases of temperate climates. Medical scientists got a bit despondent. Up till 1935 it was almost an article of faith that you couldn't kill the smaller kind of germs with drugs without killing the patient. In that year another German scientist, Domagk, announced the discovery of a remedy against the bacteria which causes septic infection. This was the first of what we call the *sulphonamide* drugs. They are made from coal tar and sulphuric acid. Many of you will have heard of M. & B. 693, which is the trade name for the sulphonamide drug most widely used in this country. These trade names—such as 606, 914, Bayer 205, M & B 693—indicate the number of compounds which had to be tried before hitting on the right one. Domagk had been following the old dye-stuff trail. The sulphonamides were introduced into the dye industry for use with certain fast dyes in 1908. They were tried in medicine in 1913, but without success. And it wasn't till 1935 that Domagk got sulphonamide compounds that would work. I'll tell you later why it took so long.

The discovery of the sulphonamides marked a two-fold revolution. In the first place it enabled us to go right in and smash up the second kingdom of germs, the bacteria. Wound infection, blood poisoning, septic throat, anthrax, puerperal fever, pneumonia, meningitis, venereal disease, dysentery, plague, carbuncles . . . all can now be cured, and still the list is not complete. These are mighty conquests which history will count as greater than all the battles of World Wars I and II. A few of the tribe of bacteria still hold out, most important perhaps the typhoid bacillus—the germ that gives you typhoid fever, and the tubercle bacillus—the germ of consumption. But the numbers go up steadily on the board as new sulphonamides are evolved—693, 760, 3714—and we have little doubt that before long we shall destroy these ancient enemies of mankind.

You will remember I said that the discovery of the sulphonamides marked a two-fold revolution. For it also marked the nemesis of German science. The Germans had led the world in the discovery of new drugs. And now they had made the greatest discovery of all. But in the moment of triumph they faltered. Was it that German medical science had been bled white for the New Order? The strange sight was seen of the Germans making a discovery and the other peoples of mankind exploiting it. For the Germans had really discovered an entirely new method of killing germs, without knowing it. That was why they had faltered on the dye-stuff trail. It was left to French and British and American scientists to follow the new track.

Bacteria, like all other living creatures, have to eat. For ten years a group of British scientists had been patiently working out the exact form in which these minute little creatures take in their nutriment. And they soon pointed out that to the bacterium sulphonamide must look just like one of its most important food stuffs. Of course its a very old principle really—the sugar-coated pill; the fisherman's fly; the sugar and plaster of Paris that kills the cockroach. But it's very effective. And now, after eight years of experiment, we have almost as many sulphonamides as the fisherman has flies.

But don't think these sulphonamides are fool-proof. They are potential poisons. They make you feel pretty blue for a day or two. And bacteria are wily opponents. If they're not properly handled, they may learn not to take the bait. So don't go taking sulphonamides on your own.

Now a peep into the future. Bacteria have natural enemies—the little fleas on the big fleas—these are other bacteria, viruses and moulds. Several attempts had been made to use these natural enemies in the service of mankind. We've even used maggots to clean up septic wounds. These satellite troops, as you might call the maggots and moulds, aren't very reliable. But scientists are finding ways to extract chemical substances from moulds—rather like the green mould that grows on stale bread—which are perhaps a thousand times as poisonous to bacteria as sulphonamide. And they're harmless to man. All this is still round the corner. But we're quite sure that it's the line of a great new advance.

But what about the third group of germs—the kingdom of the viruses? Our new drugs don't touch them. They are still impregnable. And while the bacteria may kill their thousands, the viruses kill their tens of thousands. The Austro-German armies didn't dare to occupy Serbia in 1915. The virus of typhus held the Serbian frontier. It killed nine thousand people a day. The virus of influenza killed more folk in 1919 than fell in all the battles of 1914 to 1918. Are we to wait another generation before we put a stop to their marauding and destroy them? The tempo of discovery has speeded up but it demands an increasing quota of brains and money. The brains are not easy to find. This is another fight of the few for the many. But don't let them be held up by shortage of money. A grant of £3,000 a year for seven years to the Queen Charlotte Hospital in London for the study of puerperal infection, under the direction of Leonard Colebrook, was the sum that was needed to bring sulphanilamide to the attention of the English-speaking world. £21,000. And as you know, that was not even the primary discovery of the drug. But just think what Colebrook's work has meant in life, in health, in hospital efficiency. It's already been worth a thousand times more than the cost of those seven years.

Some of the things I've been talking about must have struck you—dyes, coal-tar, electrons, television. Don't they ring a bell at the back of your mind? An echo of our war against Hitler? When it ends, mankind must beat its swords into ploughshares. Most of you know that the tank and the agricultural tractor come from the same stable, that the fighting ship and the merchant ship are launched from the same slipway. But how many realize that the cartridge, the high explosive shell, and the aircraft are made with the same materials and the same skills as our drugs, surgical dressings, and research apparatus? Gun-cotton is twin-brother of the collodion we put on a wound, nitroglycerine is our best drug for angina pectoris, your plastics are made from our carbolic acid, your lyddite is cousin to our M & B 693. This country now has an intensified war production—coal, coal-tar, fine chemicals, skilled operatives, technicians, chemists, physicists. How easily they could be adapted to the conquest of the germ.

Everyone nowadays has heard about nutrition. You who've been listening to the other talks have heard a great deal. The folly of men starving in the midst of plenty. But few people realize that under-consumption of drugs by the world is equally grievous. Effective drugs are costly, and, to put it bluntly, the great mass of mankind is starved of essential drugs. So there are two urgent needs: increased production of known drugs; increased exploitation of the technique for discovering new drugs. Mr. Wells has urged us to face up to our inheritance and our ever-growing knowledge. I suggest that those of us who live at the heart of the Empire should face up to our responsibilities. I've tried to make it clear what medical science has achieved, and what good hopes we have of more discoveries. It's very important that the ordinary citizen should know these things. When the war against the Axis is over how are you going to switch men and materials on to the war against the germ? That's the problem I'd like you to discuss.

VIII

THE CONQUEST OF THE TROPICS

By DR. W. H. KAUNTZE

IT is very nearly thirty years ago since I first saw the low-lying, mangrove-edged coast of West Africa with a few palm trees sticking up here and there. I can still remember the excitement with which we watched the surf-boats putting off from the shore for the ships, each with its crew of eight or ten African boat boys plying short paddles. It was still more exciting, but somewhat undignified, to be lifted from the ship's deck into the wildly tossing surf-boat in a mammy-chair slung precariously from one of the ship's derricks. I watched these hefty Africans pull us ashore and admired the skill with which they guided the boat on the top of an Atlantic roller till it dropped high and dry on the beach. I little realized then that these men represented the survival of the fittest, that out of every thousand African babies born, about two to three hundred died in their first year from disease or malnutrition, and that many even of these massive boatmen suffered from the effects of malaria or yaws.

You no doubt have heard West Africa described as the White Man's Grave, and may have even been told of the catch about "The Bight of Benin"—"the Bight of Benin, where few come out, though many go in". You may ask why we should go to such places. Why should we bother to conquer tropical disease? Well it would be very odd of us not to extend our knowledge of medicine and hygiene wherever it is needed, wouldn't it? And furthermore, many of the so-called tropical diseases were once found in Europe, and, to a large extent, we have got rid of them. But nowadays so many people travel quickly between the Tropics and other parts that there is a real danger of these diseases being carried, not only back to Europe, but all over the world. When one could cross the sea only in a ship, it was easier to control the spread of infection, but think of all the air-lines criss-crossing the Tropics to connect Europe with South Africa, Asia, Australia, and the Americas.

Civilization and western education have not moved so rapidly in the Tropics as in some temperate zones, and as people there suffer more than we do from disease, particularly from the forms which we think of as tropical diseases, there are, you see, important reasons why we should attempt to conquer them, and to-night I want to tell you a little of what has so far been done in this direction. It is a story which started only about fifty years or so ago, for most of our accurate knowledge of tropical diseases has come in that period. Strange as it may seem in these days, when the names and uses of vitamins and synthetic drugs are bandied about so much in the newspapers and magazines, it's only about three hundred years since Sir Kenelm Digby, a scientist among other things and a man who'd had his troubles with sickness in African ports, advised a friend to avoid malaria by carrying "live spiders in a box to soak up pestilential vapours".

Now, many of the so-called tropical diseases were once found in Europe. Why, then, have they left us to find refuge in the Tropics? Well, one reason is the higher standard of living and sanitation which has been adopted in most parts of Europe, and another is to be found in the climatic conditions in the Tropics. Professor Witts spoke of the three kinds of microbes, and said that the largest kind, "the little animals", as he called them, caused many of the group of tropical diseases of which malaria is an example. There is a close connection between this wealth of insect life and those big microbes or "little animals", for scientists have found out in recent years that these larger microbes have to live part of their lives in the human body and part in the body of an insect. The actual insect varies with the particular microbe. For example, malaria is carried by one kind of insect and sleeping sickness by another. This new knowledge of the life history of the larger microbes dates back to 1880 or thereabouts when Sir Patrick Manson, working in China, suggested the life history of the minute worm which causes elephantiasis, a disease in which the limbs swell to elephantine proportions. Through Manson's work it was discovered that this little worm, when it was an embryo, was sucked out of the blood of an elephantiasis patient by a mosquito, grew up inside the mosquito, and, as an adult, got back again by the bite of that mosquito into another human being, who thereupon probably developed elephantiasis. The discovery that these larger microbes have these peculiar life histories is of great importance, for it has put into our hands information vital to the attack on the diseases these microbes cause. This vital information is that the microbe has to live through both parts of its life-history—has to inhabit an insect *and* a human being—or it can't continue to live. If we interfere with either part, or prevent the microbe passing from man to the insect or from the insect to man, it ceases to live. So we can attack the disease which the microbe causes, by killing the insects or preventing them breeding, or by keeping the insects from biting man, or in some cases by giving to the human host drugs which don't kill him but do kill the microbe. Such a drug is quinine. It has been used for a long time in malaria, and it is still our main stand-by in the Tropics where life is primitive and doctors few and far between.

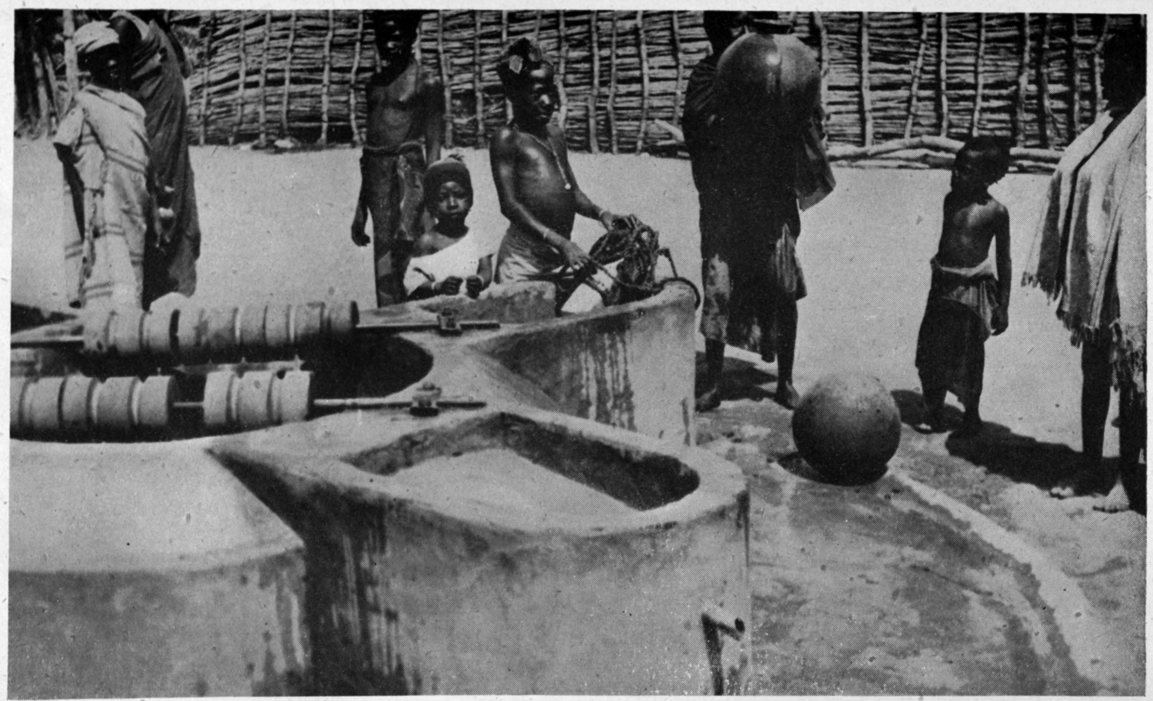
But this knowledge about the life-history of microbes has not been obtained without effort or sacrifice. Some part of it has only come as the result of years of work, scientists adding a little knowledge here and a little knowledge there until the complete jig-saw puzzle was complete.

Take the story of malaria. Of all the diseases which afflict dwellers in the Tropics this is the most important, not so much from the deaths it may cause, as on account of the ill-health and loss of energy repeated attacks produce. We now know that we can get rid of malaria if we can only get rid of the mosquitoes which carry it. But less than fifty years ago no one knew this. Men then thought malaria came from drinking bad water, or from breathing mists rising from swamps, or from breathing bad air—hence the name "mal-aria". But the man who had suggested the life-history of the worm which caused elephantiasis, suspected that the microbe of malaria might have a similar history, and he urged Dr. Ross (who afterwards became Sir Ronald Ross), who was then a member of the Indian Medical Service, to begin a series of investigations on these lines. Though he met with success, a success shared with the Italian scientists, Grassi and Marchiafava, it was a long and wearisome road that Ross had to travel. He had no idea which of the many dozens of kinds of mosquitoes in India was likely to carry malaria, nor had he any clear picture of what the microbe inside the insect might look like. It is not surprising, therefore, that Ross was often tempted to give up his task in despair. He might indeed have done so, had it not been for Manson's constant encouragement. At last, however, his observations produced the results he was seeking, and made it quite certain, one would have thought, that malaria was indeed carried by certain kinds of mosquitoes. But Manson was not even satisfied with this. He felt a practical test was necessary. He therefore had sent to England from Italy mosquitoes which had fed on patients suffering from malaria. On their arrival he allowed them to bite two healthy men who volunteered for the experiment, one of these being his own son. Both victims developed malaria. Then Manson, with three friends, went to a notoriously malarious spot in Italy, and lived there right through the malaria season of 1900 in a mosquito-proofed hut brought from England. They were careful to stay in the hut from dusk till well after daylight, this being the time of day when mosquitoes were most active. Although the neighbouring country folk suffered severely from malaria, Manson and his friends did not develop it at all. Manson's theory was proved.

This double experiment set the seal on the discoveries previously made. Henceforward sanitarians knew that the elimination of the mosquito was the secret of the control of malaria, and application of this knowledge on a large scale has cleared many towns in the Tropics of the disease.

The story of the discovery of the way in which malaria is carried is one of perseverance in the face of many disappointments. It is the story of Bruce and the spider all over again. The yellow fever story is more dramatic and more tragic. Just as in the case of malaria, the cause of this disease, which had at times decimated cities and seaports in the West Indies and Tropical America, was then unknown. Some observers believed it was caused by breathing the exhalations from a person sick of the disease. Others thought it was due to touching clothing which had been worn by the sick. Others, again, thought it was due to the unsavoury, filthy conditions of the cities where it occurred. A man called Carlos Finlay did, however, suggest that yellow fever might be carried from man to man by the mosquito. This was in 1881. It was, however, nearly twenty years after that before the American Commission of 1900, headed by Major Reed, was appointed, and this was only done then because of the enormous numbers of American soldiers who were dying of yellow fever in Havana. The Commission soon found out that mosquitoes could carry the disease, for one of its members, Carroll, was accidentally bitten by an experimental mosquito, and in four days was dangerously ill with yellow fever. Fortunately he recovered. Another member of the Commission, Lazear, was not so lucky, however, for he got bitten by another mosquito and died. The Commission, however, considered they must also show that the popular belief that the disease was due to contact with infected clothing, was wrong. They therefore had a mosquito-proofed hut built, and in this were placed the beds and bedding of patients who had recently died of yellow fever. In these beds there slept for a number of days a doctor and some Army privates who had volunteered for the test. When we consider that at that time it was popularly thought that yellow fever was caught from the bed linen and clothing of the sick, and furthermore that some 70 per cent of yellow fever patients died, we cannot but admire the heroism of the men who took this risk, in cold blood. None of these volunteers did in fact get yellow fever, but it still remained to be seen whether they could contract yellow fever, or whether they had some natural resistance which prevented them getting the disease. So once again they exposed themselves to the risk of infection, this time by the bite of an experimental mosquito or by the inoculation

BABY BEING INOCULATED AGAINST DIPHTHERIA



[*By permission of Dr. Nash, Senior Entomologist, Nigeria*

WELL IN ANCHAU, NIGERIA

of blood from a patient. All fell ill of yellow fever and the tests were thus complete. I am glad to say that these brave men all recovered.

As a result of the work of the Commission those towns in the Americas which were formerly hot-beds of yellow fever, were made safe by measures which were simply attacks on the carrier mosquito, which, incidentally, is a different kind to that which carries malaria. In South America these measures were organized by the International Health Division of the Rockefeller Foundation, to whose staff we are largely indebted for the modern technique of keeping down mosquitoes in towns.

But life for the tropical sanitarian in regard to yellow fever was still not so simple as it might seem to have become with these discoveries. While epidemics of yellow fever were stamped out in towns, unexpected and unexplainable isolated cases suddenly began to be found in rural areas, sometimes in places where the proved urban mosquito carrier of yellow fever did not exist. So once again investigation had to begin. It was then discovered that the mosquito which causes yellow fever in towns, has relatives which can also transmit the disease, and are responsible for carrying it in rural areas. These, of course, are not under such easy control as in urban centres, so that other measures to stop the disease had to be taken.

Now the microbe which causes yellow fever has never yet been seen, because it belongs to the third group of microbes mentioned last week by Professor Witts, the viruses. We can only recognize a virus by its effects on the people or animals it attacks because it is too small to see under an ordinary microscope. In the course of the investigations which have been made on yellow fever, a strain or race of the microbe has been found which, although it still infects man, has lost most of its power to cause a severe illness and at most may perhaps cause a slight headache. It has become what scientists call attenuated or weakened. This discovery has enabled a vaccine to be produced which, when injected into man, protects him from yellow fever for a couple of years, and now permits us to control the disease in rural areas.

In the development of this vaccine the International Health Division of the Rockefeller Foundation in the United States and the Wellcome Bureau of Scientific Research in this country have played a leading part.

I have told you this evening something of the drama of the search for the causes of two tropical diseases. The history of tropical medicine is full of stories like that: how Noguchi and Young, the latter a member of the Colonial Medical Service, died looking for the microbe of yellow fever in West Africa: how, to test a theory, Corson, also a member of the Colonial Medical Service, inoculated himself with blood from animals infected with the microbe of sleeping sickness and himself got the disease: and there are many other stories of like character. I hope, however, I have told you enough to show you that we have made some advance in our campaign on tropical diseases. We still have a long way to go before we finally conquer them, but we can find comfort that we have gained so much knowledge of their control in so short a time. We now have to apply our knowledge, and this is in some ways the most difficult part of our task. I said earlier that disease is still widespread in the Tropics. Why is this so, in spite of all our discoveries of the past few years? Is it because tropical peoples are largely agriculturalists and it is more difficult to apply control in rural districts than in towns? Or is it perhaps due to the different customs and ways of life in these parts? What part must we give to education for health if we want to conquer the Tropics?

IX

THE BANISHMENT OF PAIN

By L. J. Witts.

One of my teachers used to say: "Empires may rise and Empires may fall but the dose of opium remains one half to three grains." Men have used opium since the dawn of history. If you want some opium, all you need to do is to grow a field of poppies under a hot sun. Then, when the capsules form, make a little nick with a knife. You will find that a sticky juice oozes out. Just let this dry and you can collect it into cakes of opium. But remember I said a hot sun. It is no good trying to grow opium in Great Britain. So opium is one of our most vital imports. If ever things got so bad that we doctors were restricted to one single drug, then we should choose opium: "the Grand Old Medicine" another of my teachers used to call it. What untold suffering it has eased! Of course we do not often use crude opium. We use morphine, codeine, heroin. They all come from it. We can give them by injection.

A hundred years ago alcohol and opium were the only anæsthetics. They are not much good as anæsthetics. It is not safe to give enough to stop the pain of the knife. And a man who is dead drunk is not in the ideal state for an operation. So most operations were done without anæsthetics. How dreadful the cries and struggles must have been! Speed was everything. There were records for operations as there are for the half-mile or the Derby. When Mr. X, the famous surgeon of early Victorian days, took the leg off right through the thigh in under three minutes, the whole hospital buzzed with the news. You could not do good work under these conditions. To remove a tumour of the brain, for example, takes infinite care and skill, but there were over a hundred such operations at my hospital last year. A brain operation often lasts seven or eight hours. It is more like an artist painting a miniature than the old-fashioned idea of an operation. Line by line, stroke by stroke, millimetre by millimetre. The bloodless field, the sharp focussed light peering into the depths of the cranium, the elaborate ritual to prevent the entry of infection. The surgeon must break off at intervals for a sandwich or a cup of tea, but the anæsthetic continues throughout. The delicate valves of the anæsthetic apparatus flutter and fall twenty times a minute, hour after hour. The blood pressure drops slowly. The anæsthetist swings round on his stool and sets up a transfusion. And so it goes on: the silent drip of the blood transfusion, the quiet hiss of the oxygen; the small restrained movements of the surgeon. A hundred years of progress. People in the eighteen-forties thought they were living in exciting times. The French king lost his throne, there were the revolutions and the barricades; and in this country we had the Chartists, the corn laws, the birth of trades unions. But those were not the most important things. The red letter days were: 1842—introduction of ether; 1844—laughing gas; 1847—chloroform.

Since those days, the anæsthetist has made advances on two lines. He has gone on inventing and improving apparatus to make anæsthetics safe and fool-proof. The latest example is the Oxford vaporizer. This lets the anæsthetist set the flow of ether for a particular patient and operation just as the housewife can set the modern oven for the particular dish she wants to cook. And so in the rush of war casualties the anæsthetist can supervise several operations at once. The other advance is what we call premedication. Premedication means that you are given drugs before the anæsthetic so that you fall fast asleep. All credit to the German chemist who gave us these drugs: avertin and so on. And all credit to our own chemists and the Americans, who have made them for us in time of war. Just a pinprick in your arm. You wonder when they are going to start. Then dimly you see a blue and white figure sitting by your bed. A kindly voice, "Well, you feeling all right now?" It's unbelievable. "All over? It went successfully?" "Yes, beautifully," says the nurse. And again the comfortable tides of sleep submerge you.

Then there is cocaine, another ancient drug. But cocaine was not used as a local anæsthetic until the eighteen-eighties. The chemists later found out how to make it artificially. In fact the chemists have played with cocaine as a musician plays with a theme for variations. Now we have special cocaines for anæsthetizing the eyes, the throat, the nerves, the spinal chord or the itching skin. We can carry out the most severe operations under local anæsthesia. And the patient stays wide awake, the mind quite unaffected. In fact the surgeon can even remove his own appendix like this. It is curious that surgeons and anæsthetists often choose cocaine when they have to have an operation themselves. But put me to sleep every time.

Anæsthetics are not the only means of banishing pain which have improved in the last century. Do you ever read the old diaries, Samuel Pepys and the like? If so, you will remember the awful toothaches and neuralgias that sometimes filled their thoughts for days on end. Or the pains of gout that turned kindly men into savage bears. Was it any wonder that sensitive or sleepless souls took to drink or to opium, and that the bright promise of men like Coleridge was extinguished? Think of these things the next time you shake an aspirin out of the bottle or when you are given a sleeping tablet for insomnia. The earlier remedies, alcohol, cocaine and opium, degrade the sufferer if they are used too often. It has been the triumph of the chemist to produce drugs which relieve pain or bring sleep without that fearful penalty.

It was in those same eighteen-eighties that the chemists were studying the coal-tar molecules. They produced a number of drugs that would relieve pain and fever. They flooded the little village shops with headache powders and teething powders. But these were all rather dangerous. Sometimes they turned the grown-ups a deep blue colour and sometimes the poor little babies did not live to cut any more teeth. Then in 1899 came aspirin. A lot of hard things have been said about aspirin. It gives some people rashes and swellings and asthma and even gastric ulcers. All the same, the credit balance is a high one. It is a most effective and fool-proof remedy for the minor aches and pains of life.

For a drug that can be put in anyone's hands it comes very near perfection. I put aspirin high up on the list of human inventions. So does the ordinary citizen, if we can go by the amount consumed. Before the war the figure was fifty aspirin tablets a year for ever man, woman and child in these islands. Quite frankly, that seems to me excessive. I just don't believe there was enough pain to justify the consumption of so much aspirin. And what was the penalty? Approximately sixty deaths a year attributed to aspirin, of which forty-eight were suicides. To see these deaths in perspective, you must compare them with two thousand deaths a year from coal-gas poisoning, of which eighteen hundred were suicides. These modern inventions, the gas-oven and the aspirin tablet, have their price. They provide too easy a way-out of life for people who are depressed, perhaps depressed only temporarily. But again I say, don't forget the misery they have displaced.

Sleeping tablets, or hypnotics as we call them, are much more dangerous than aspirin. For this reason people are not allowed to take them without medical supervision. But I have a point to make in relation to the modern group of hypnotics which are known as the barbiturates. They came in before the last war but they have been greatly developed since. They not only promote sleep but they relax tension. Now tension is one of the most fruitful sources of pain in modern life. I would give up a large part of the pharmacopœia for the barbiturates. But they have their risks. Some people were so impressed by these risks that they tried to stop the growth in popularity of these drugs. And so what was called the Battle of the Barbiturates was fought in the medical press in 1934. Fortunately, as I think, the barbiturates won through.

Now the point I want to make is this. It is an extraordinary thing—you know how we all hate the thought of pain for ourselves or those near us—that new methods of relieving pain have often had to face strong opposition. For example, ether and laughing gas were received with hostility and incredulity. When Simpson began to relieve the pains of childbirth with chloroform, he was treated as an enemy of religion. In the end Queen Victoria herself had chloroform for her babies and all was well. The

German scientist Schleich, who introduced local anæsthesia with cocaine, was more or less booed off the platform when he reported his results in 1892. And to-day we have the Battle of the Barbiturates, and we know that many women still have to go through the ordeal of childbirth with no more relief than Mother Eve. What is the reason for this attitude? Has the process of evolution been so painful that we have had to learn to shut our hearts to suffering? Or is it the sense of guilt and the need for punishment which have dogged Western civilization throughout its unhappy history? I do not know the reason, but I am sure of the facts. There is still a great deal more pain in the world than there need be.

Pain, then, is something we can assuage with drugs. We can show under the microscope the nerve terminals at which pain arises. We can follow the passage of impulses of pain up the nerve just as we can tap a telephone wire. We can show that something is produced at the nerve centre just as the telegraph produces a message on a tape. Our drugs block these impulses. They blot out the telegraph messages.

But if I stopped here, in a talk headed the banishment of pain, a lot of you would suggest that there are certain questions, certain techniques, which I had been afraid to deal with. Let me explain what I have in mind. A friend of mine had a patient who was suffering from an incurable painful disease. One day this lady said to him, "Doctor, you have more or less indicated that my illness is incurable. Would you object if I consulted a mental healer?" It was pretty clear her days were numbered. So my friend gave his consent. A fortnight later he called on his patient. He was surprised to hear she was walking in the garden. He went out there. She looked deadly thin and ill, but she said that as a result of the mental treatment she was quite well and had no pain. A few days later she died.

Well, you say, she was just pretending that she felt well and had no pain. But all of us know that if we injure ourselves in the heat of a game or are wounded in battle, we may not feel the hurt until later. Open any textbook of diseases of the nervous system and you will see photographs of hysterical young women smiling cheerfully, although safety-pins have been fastened through the flesh of their arms. Travellers tell us about savages who insert skewers through their cheeks. And in those same wonderful eighteen-forties hundreds of major operations were performed under hypnotism and were said to have been quite painless. These results aroused the most violent controversy at the time, just as laughing gas, ether and chloroform did, but there is little reason to doubt their truth. Unfortunately the technique was not developed because it was easier to use ether and chloroform.

At intervals since then devotees of hypnotism and mental healing have arisen. But the whole business has always been in rather bad odour. Scientists are like dogs: liable to bark at what they do not understand. But with the deeper study of psychology in the last fifty years, we can visualize how one current of forces can block another current of forces in the mind, just as one wireless station can jam another station in the ether. And just as you can tune a wireless set on or off a particular station, so in excitement or hysteria or hypnotism the mental apparatus may no longer respond to the wavelength of pain. We have learned—and it has not been an easy lesson—that many painful dyspepsias and rheumatism and the like are due to faults of the mind rather than the body. Though they may be relieved by a drug, they can only be finally removed by securing a healthy mind in a healthy body. We have been busy, these last hundred years, with chemistry and physics and bacteria and drugs. We have surpassed some of the dreams of the old alchemists. But all these years men have been recording the facts about hypnotism and hysteria and suggestion and mental forces. The pioneers have been clearing the ground for a science of the mind. We do not use hypnotism now for operations. But perhaps we might use something like it for childbirth. It might be safer for the child, less likely to hurt it than drugs. Don't think that scientists are not aware of mental forces. The waves of research swirl from one channel to another but the tide of knowledge rises all the time.

X

PREVENTIVE MEDICINE

By Professor James M. Mackintosh

Queen Victoria's own apartments at Buckingham Palace were once ventilated through the common sewer, and Parliament had to meet with the windows shut because of the stench from the Thames. But the counter-attack on such conditions, I am glad to say, had been under way for some time. The publication of Sir William Beveridge's report last year was a fitting celebration of the hundredth birthday of preventive medicine; for it was in 1842 that the first scientific report on the sanitary conditions of Great Britain was issued and the first time that *prevention* took its right place in official records. Edwin Chadwick, who was not a doctor at all but a very great expert in government, wrote that Report, and he says in his introduction this: "Abandoning any enquiries as to remedies or treatment of disease after their appearance, I have directed the reports of medical officers, chiefly to collect information of the best means available as *preventives* of the evils in question."

Man, up to now in this series, has been seen as a pioneer and explorer, conquering his natural enemies—from germs to rats; reshaping animals and food-plants; harnessing water to make fertile soil from deserts. But the public-health battle has been, not an expedition but, as I've just said, a counter-attack, for the chief faults of our surroundings have been of our own making: bad housing, defective sanitation, and polluted water supply. These were the results of the machine age, when people crowded from the country into the dismal slums of the industrial towns. When this great Industrial Revolution began, in the middle of the eighteenth century, only one-third of our people lived in the towns; to-day nearly three-quarters of them do so. The unhappy thing about this change was that we weren't ready for the appalling problems of dirt and disease it led to. A century ago, there wasn't a single general law on Public Health, and indeed the most active and persistent reforming power was fear. Fear of cholera particularly, which was a deadly infection and used to break out in this country in terrible epidemics. Fortunately another thing Chadwick had done was to get the Registration Act of 1838 in the Statute Book. Deaths then had to be registered with all proper details and so, in the cholera epidemic of 1848, when 54,000 people were wiped out in England, it was possible to deduce that the disease was spread by drinking water infected with sewage. Unfortunately most town drinking water was infected with sewage. Not everybody, of course, was in favour of cleaning up. For one thing, fear is a fickle counsellor. As the Old Chronicler said: "So long as the plague was hot and fervent, so long every man was holy and repentant; but with the slaking of the one followed the forgetfulness of the other." Then in 1853, when there was another threat of cholera, the Presbytery of Edinburgh asked Lord Palmerston, the Home Secretary, whether a National Fast should not be appointed by Royal Authority. Palmerston, a humane man with a proper appreciation of sanitary precautions, replied that the best thing people could do to *deserve* that the cholera should be stayed was to cleanse their towns from the sources of contagion which (in his own words), "Will infallibly breed pestilence and be fruitful in death in spite of all the prayers and fastings of a united but inactive nation. When man has done his utmost for his own safety," he added—in words that we might still take to our hearts—"*then* is the time to invoke the blessing of Heaven to give effect to his exertions."

But all through the time when the great towns were taking a leading part in the battle against the worst evils of slum-life, and against the long hours and unhealthy conditions of work too, their worst enemies, who made it a hard and often pretty depressing struggle, were prejudice: all the people who didn't approve of the new ideas and anything being done for the first time; apathy; all the people who didn't see why they should care; and the interested parties: the people who believed that the improvements would stop the wheels of industry and interfere with the established rights of property.

All the same, the reformers went right on making steady progress—which isn't surprising, as they were obviously getting results—and towards the end of Queen Victoria's reign what Chadwick called "the sanitary idea" had firmly caught on with the public and Parliament too, and was a political issue of the first importance.

But there was a catch somewhere. Everything seemed to be working so well, and yet it became only too clear that there was a great mass of preventable sickness lying beyond the reach of houses and drains. A shocking number of babies still died; school-children were often sickly and unable to get the good of their education; and young adults were in such poor physical condition that alarming numbers of recruits for the South African War were rejected on medical grounds. In fact, the evil alliance between poverty and ill-health couldn't be broken by sanitary reforms alone. I think the "catch" was this: that sanitary science was too impersonal; it thought too much about protecting the community and too little about helping that Mrs. Smith and Mr. Jones, and Mrs. Thompson's baby.

So the twentieth century opened with a new idea of health. The individual person came much more into the picture, especially the children, and this led to the infant welfare centres where mothers were taught how to look after their babies, and where they could go freely for advice about the little troubles of everyday management. Then it didn't seem enough to start with the baby after it was born, and clinics for expectant mother were set up, where any approaching difficulty or risk could be met half-way by the doctor and often entirely checked. Next, and with just the same idea—of caring for actual people one by one—we got the school medical service, with doctors and nurses looking after children year by year and *preventing* much sickness, catching and treating defects early and *preventing* any serious consequences. Quite recently we have started to fill a gap by setting up nursery schools, and we've been trying to see that children had extra food for their growing bodies, school milk, for instance, or four times as many eggs as you and I get. And the time is coming when each child will be followed up right to the gates of adult life. Perhaps you will say, "This is all very well, but if you go on developing these public services and set up nursery schools and provide school meals, won't you take away too much responsibility from the parents, and—what's the phrase?—'sap the sturdy independence of the British people'?" Now this is a perfectly fair question. I would answer it like this. You must draw a sharp distinction between mere doles or hand-outs, and services which have a positive educational value. Benefits which carry with them no social responsibilities are worthless; doles are demoralizing. But all health services encourage self-reliance and responsibility; they help the mothers to help themselves—everyone who has any real knowledge of them can tell you as a fact they do.

Many a time I have said to a nurse during a school medical inspection: "How beautifully that mother keeps her children"; and the answer was, "Oh, yes, but she was a 'welfare' mother."

Now I want you to notice another change of outlook, but I can't describe it very well because the change is in the middle of taking place at this very moment. The early sanitary reformers, you remember, gave all their attention to people's material surroundings: drains, mud, paving-stones, and the rest. More recently we've gone in specially for personal health—how to stop Mrs. Smith and her family from having the diseases which we thought they might easily get, once we had a good look at them.

The time has come for something else: we need to unite these two streams of progress—the one about the surroundings and the one about the person—and carry onward all the health and medical services together in one stream, called "social medicine," or the study *of* a person *in* his surroundings.

I must try to tell you more exactly what I mean. The picture a doctor sees of a patient in hospital, in his surgery, or even in the sick person's home, is incomplete; it has no background, unless he knows about the *patient's* background, the social factors that influence the illness. And it's just these very factors—the home surroundings, the conditions of work, and the personal relations between a patient and his family—that so often pour a flood of light on the cause of his illness, the treatment that should be given, and the ultimate outlook. It's a true saying that it is much more important to know what sort of a person has an illness than what sort of an illness a person has. It may be rheumatism, or headache, or stomach trouble that the patient complains of, but deep down in its root the real cause is a conflict related to his work or his family life. Knowledge of the social background may tell us, for example, how useless it is to send a patient back from hospital to the work that caused his illness or to the family strife that produced his symptoms. That is the main reason why so many hospitals find that trained social workers on their staff are just as important as doctors and nurses.

I want to underline a point I've just made. Social medicine mustn't be practised only when a doctor has a case of illness in front of him. It is even more vital to prevention, but wait, there's a better word for what I want: vital to the *promotion* of health. And that means mental health as well as bodily health. More education in health.

Under the present system of medical service the doctor is called in only when a member of the family is actually ill, and National Health Insurance does nothing to encourage him to act as adviser on health. The Public Health services are under a separate authority and there is no real link between the two. Even the factories, where so much of the worker's day is spent, are outside the sphere of the family doctor, and the present arrangements for restoring a disabled worker to full efficiency are chaotic. Some much more closely-knit plan of campaign is essential.

Some of you may have heard a discussion broadcast last month on how best to organize comprehensive medical services for prevention and cure, and make them available to all. There are very different points of view held by doctors, and explained in that discussion, and I can only tell you what I think myself. It's up to the community to decide.

Take the case of John Smith, for instance. In my opinion he should be under the care of the one and the same authority, whether he is in the workshop, or in his own home, or in hospital; whether he is a fit man or a sick man. Secondly, we must learn to turn our eyes away from sickness, and take a good look at wholeness for a change. Thirdly, and here I think doctors—generally speaking—are agreed, we should set the standard of medical care by human needs and not by family means. The health services should be made for Mrs. Smith, not Mrs. Smith for the services.

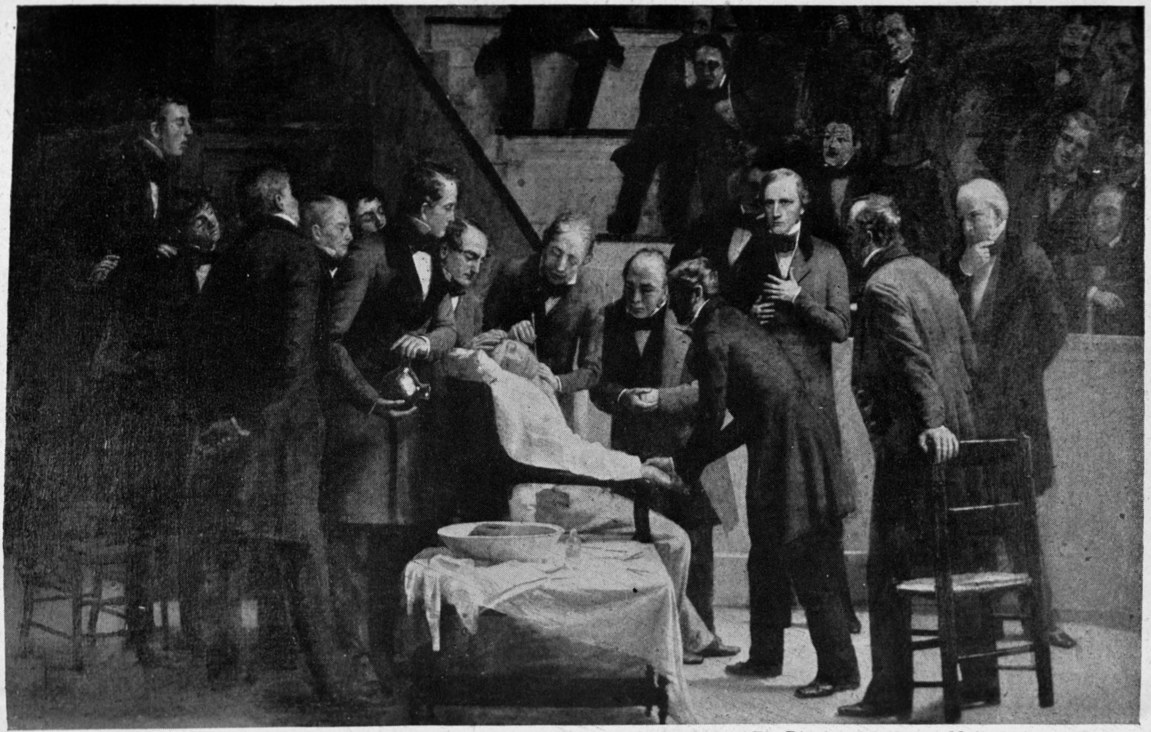
Should we make the medical services free to all as a citizen-right? Of course they have to be paid for—through insurance or taxation. So have the police, but no one ponders whether he can afford it, before "asking a policeman." So has education, but State education is open to those who accept its service. To my mind the case for free health is the strongest of all, and it's wasteful and it's indefensible that Mrs. Smith should have to count the cost before getting a doctor to examine her little girl's sore throat—if it turns out to be diptheria a few hours' delay may be fatal. It's not a bright illustration. Mrs. Smith could and *should* have protected her little girl against diphtheria by having her immunized. It's less widely appreciated that Mrs. Smith should be able, without let or hindrance, to get medical advice about her boy's fitness for a particular job, or her own indifferent health without there being any actual illness in question. Without that we are only doing half a job on prevention: if the boy goes to work which is mentally or physically beyond him, he runs a chance of a quite unnecessary breakdown. Then it's much more trouble and expense to the community to cure him than it would have been to study his health at the beginning and decide what kind of work he could do best.

Some authorities consider that these services can be provided under the present system of competitive medical practice. Personally, I don't. To my mind we need a National Health Service covering the whole field of medicine—public health hospital and general practice. I think this means we should have a salaried medical service, cutting competition out of health altogether, and replacing the present "panel" system. I know there are those who think, either that competition is in itself a good thing, or that you can't get rid of it under any form of organization. I don't agree. But I don't agree either with those who want medicine to be a civil service, controlled by a remote centre in London. I'm in favour of variations according to local needs, and developments along the lines of local tradition; I think that what suits Manchester or Birmingham would be quite out of place in the Yorkshire Dales or the Scottish Highlands. But anyway, the most important social consequence of the new system would be that the doctor would be enabled to attend the families under his charge in health as well as in sickness. He would become *in fact* a health adviser. This change would be quickened and made more effective if we provided health centres for every community.

The second thing required so that social medicine can be firmly established in post-war reconstruction is to bring order into the existing confusion of hospitals and clinics. Nearly all doctors are agreed on co-ordination between the voluntary and the municipal hospitals. There are different ways of going about this, but for my part I'd like to see the country divided into regions, and all the hospitals in each region working together as a team. Of course this would mean that each hospital would forego some part of its independence in order to be fitted into the general pattern. But there will be no pinnacles for the solitary after this war. And lastly, there must be a much closer link between industry and the health services. How should this be worked out? How do you think the rehabilitation work that's already been begun should be fitted in? This whole vast problem of restoring the disabled needs to be tackled by co-operation between health and industry, and health in industry is just one aspect of community health. All the disabled, including the blind, the cripples, and those who are partially unfit for work from disease or accident, have two features in common:

1. They need, according to their capacity, some useful and productive occupation. Something that will really satisfy—not just playing at work.

2. They can't compete with their fellows in the open market. What should a socially-minded nation do for them, in its own interests as well as theirs? Isn't the simple answer that it should provide for them occupations through which they can be reinstated as full citizens in industry—preferably in their own job? The ideal job for a disabled man is his own job, and don't you think our first aim should be to get him back to his own work? At any rate we can't afford to neglect them; they must be given interest and hope; discipline and freedom. They don't want charity, but to my way of thinking it should be a part of the State's responsibility for social medicine to assist them to find a place in industry under controlled working conditions and expert medical supervision. I spoke a few minutes ago about the evil alliance between poverty and ill-health—the Axis at home. The new medical services should go all out to break the Axis by providing opportunity for health.



[*By courtesy of The Director of the Boston Medical Library, U.S.A.*

FIRST OPERATION UNDER ANAESTHESIA

XI

MAN'S LENGTHENING LIFE

By MAJOR P. GRANVILLE EDGE

SOME three hundred years ago a London haberdasher, named John Graunt, was devoting quiet attention to a field of work which, hitherto completely neglected, was to have the most valuable and far-reaching results. He began a critical examination of the London Bills of Mortality, documents containing data relating to deaths from all causes, and deaths due to plague in the various parishes of London, first prepared as weekly returns by the Company of Parish Clerks towards the middle of the sixteenth century. The primary function of these returns appears to have been to provide a means of warning members of the Royal Household and other important persons of the fact that cases of plague had been recorded, so that those able to do so might take their departure from the infected city. For the rest the Bills were ignored until Graunt used the data contained in them as bases for reasoning, and, refusing to adopt conclusions without the support of adequate numerical evidence, was able to bring to light many important and hitherto unsuspected truths. The influence of Graunt's studies, published in 1662 under the title of *Observations on the London Bills of Mortality*, was reflected in the works of numerous disciples who followed and slowly built on the foundations so well prepared by the London haberdasher.

But it wasn't until the establishment of compulsory civil registration in this country in 1836, which Professor Mackintosh mentioned last week, and the appointment of the great demographer William Farr, that the numerical method came to be recognized as the key to several sciences, and as a scientific tool as important to the medical investigator as is the microscope. William Farr was an English Medical Practitioner who was to become the official interpreter of the life and death ledgers of the newly-created English General Registry Office. In his appointment we see an outstanding example of how a man may be especially endowed by nature and fortuitous circumstances to undertake successfully a specific mission, for under the inspiration of Farr's genius medico-statistical procedures and techniques in England and Wales became the model for the world to imitate. His methods were simply these: he collected, analysed, and interpreted an infinite variety of facts with a view to the discovery of the causes responsible for the phenomena characterizing all human lives from birth to the grave; his talent lay in doing a simple ordinary thing in a manner so transcendently out of the ordinary as to amount to genius. His illuminating analyses of mortality data emphasize the importance of mortality rates as measures of the sanitary condition of a country, their value in the construction of Life Tables, their function in enquiries into occupational mortality and so on. In an age when bacteriology was unknown, he was nevertheless able to throw light upon the exciting causes of epidemic outbreaks of disease, and the modes of spread, course, and size of epidemics.

And so we find that by applying numbers to illustrate and measure the natural history of man in health and sickness, we have a means of demonstrating in simple, convincing, and summary manner, the actual condition of a population group, what progress towards better health has been attained, what deficiencies remain to be remedied, what are the prevailing diseases, which causes are taking an undue toll of precious human material, and the relations to each other of various influences harmful or beneficial to human health and progress.

And that brings me to the title originally selected to distinguish this talk—a title which so far has been purposely avoided, for to speak of "Man's Lengthening Life" postulates the notion that medical science and sanitary reforms introduced in the interests of public health have proved so eminently successful that nowadays we live longer than did our ancestors.

In one sense, of course, the notion is true, for a far larger proportion of live-born children grow up to manhood and womanhood than was the case, say, a century ago. Then, out of every 100 male babies born alive in England and Wales, about 65 survived to the age of 20, and about 53 to the age of 40; of 100 girl babies, 67 lived to the age of 20 and 55 to the age of 40. Nowadays approximately 87 boys and 89 girls out of every 100 of each sex survive to the age of 20, and 81 boys and 84 girls in each 100 live to the age of 40. That is an enormous improvement. But that we live longer in another sense—that is, in the sense that the "natural" term of life has increased, and that we are getting back to Methuselah in Mr. Bernard Shaw's sense—is *not* true, for it is not clear we *do* live longer than did our ancestors. For example, out of every 100 men who were aged 60 a century ago, 63 lived to be 70, and of every 100 women sexagenarians 66 lived to be 70. At the rates of mortality of 1930–32 the survivors would number 68 and 76 respectively.

Two objections can be made: *firstly*, that there is evidently some improvement for clearly 68 is larger than 63, and 76 is larger than 66; and *secondly*, the rates of mortality at the older ages may improve still further.

But, if we suppose—as we must do—that the greatest part of the improvement between birth and the age of 40, is due to a saving of obviously culpable waste of life (such as we now appear to tolerate on our high roads), and admit that some lives of elderly people are recklessly destroyed, we can hardly infer from the evidence that a normal or natural term of life of 100 or even of 80 years is likely to be realized in a foreseeable future. The biology of mortality at old age is still little understood for we still have too few accurate data of the mortality rates of people over 80. We ought therefore to think of increased length of life in the first rather than in the second sense; namely, as a measure of increasing economy in the use of life, rather than as some foreshadowing of a golden age of longevity. Modern aseptic surgery, the arrest or cure of diabetes, the treatment of diseases with new drugs, and so on, depend upon scientific knowledge hard to obtain of which our great-grandfathers knew nothing—these collectively have saved thousands of lives. Millions of lives have been saved by housing people better, by feeding them on more but less dirty food. Our ancestors were quite as convinced as we are that good houses, and clean and sufficient food and water were excellent in themselves, but they appear to have lacked the imagination and knowledge that would have stimulated action to provide clean water supplies, satisfactory sanitation, well-built houses an adequate transport services for the carriage of ample supplies of good food to every corner of the Kingdom. So it would seem that we have travelled so far as we have along the long road towards health betterment, not wholly or even mainly by recondite knowledge, but by the exercise of imaginative commonsense. The wastages of valuable human material caused by such diseases as typhoid fever, diphtheria, and some other infections, have been enormously reduced, but these diseases should and could be entirely eradicated. In our own country since the beginning of the present century, the infant death rate has been reduced by nearly two-thirds; deaths at all ages due to tuberculosis have declined by more than half and could be reduced still further. Yet, despite all that has been done, available knowledge has not yet supplied the means to remove preventable sickness and enable everyone to live healthfully to the end of the natural span of life.

So far we have spoken only of conditions in our own country, and it will be natural to enquire what progress can be reported from our overseas Colonial territories in the tropics where strange diseases are common, where climate also appears to tyrannize over and enfeeble the human frame, and where of some of them in the past it was commonly said there are only three topics of conversation—debt, disease, and death.

In 1837 William Farr, in an article contributed to McCulloch's *Descriptive and Statistical Account of the British Empire*, observed that a soldier in the prime of his physical powers was more liable to death with every step he took away from his native climate, and that such a soldier, aged 28, was then subject in the West Indies to the same risk of dying as a man of 80 remaining in Britain. The phrase, "The White Man's Grave" epitomized the sinister reputation in the matter of health peculiar to West African territories, where less than fifty years ago a prominent Lagos newspaper pressed that something should be done to relieve the local grave diggers, who were at work every day from 6 a.m. to 6 p.m., Sundays included, for the Grim Reaper was busy every day. Ignorance and shortsightedness brought tens of thousands of lives to an untimely end in the tropics a bare half a century ago.

Since those dreadful days, great advances have been made in the control of what are termed tropical diseases, and considerable success has attended efforts directed towards the health betterment of millions of people whose outlook, customs, and standards of education and life differ so widely from European experience. It must be remembered, too, that apart from epidemic diseases, the impact of invading races upon indigenous peoples resulted in the introduction of new diseases, against which the local inhabitants lacked immunity or had but low powers of resistance. The rapid expansion of industrial and commercial activities had far-reaching effects upon the lives of such peoples, and improved communications provided increased opportunities for the spread of disease. Numerous instances might be quoted indicating the rapidity of spread and the unusual virulence of a disease when first introduced among an aboriginal reservoir, as for example in the case of Fiji in 1875, when, on the first introduction of measles there the disease was responsible for the deaths of 40,000 persons in a population of about 150,000 Nowadays we find that tuberculosis, pneumonia, and other respiratory affections are among the principal killing diseases, while rheumatism, and other familiar titles, are prominent in the lists of disabling ailments among the people to whom I have referred. Much has been done for the relief of these people, but in spite of all the progress made, the measurement of many aspects of public health improvement with any degree of accuracy has so far proved impossible in many cases owing to the fact that dependable data in sufficient quantity and detail over extended periods of time are not available.

These observations mustn't be interpreted to mean that efforts aren't being made to obtain data characterizing the lives of these people. From all territories fundamental facts have regularly been assembled, permitting the calculation of crude rates which are generally accepted as primary measures of the sanitary conditions of a country and its people, but these crude rates are only preliminary assessments of the combined effects of innumerable influences—they mask the several individual influences at work, and their importance when acting alone or in combination. For example, the crude death rate in a certain tropical colony was 21.0 per 1,000 population, but this figure hides the fact that death rates in the various provinces of the colony ranged from 17.4 to 37.0 per 1,000, while in the subdivisions of those provinces the district death rates ranged from 15.3 to 48.8 per 1,000. In such a case as this, the crude death rate for the colony as a whole, if used alone, would prove of little public health assistance, for it would fail to direct the attention of the responsible authorities to the presence of local influences which, in their various combinations, had the effect of depressing mortality rates in one area and raising them in another. This is a very elementary example of the limited range of usefulness embraced by a crude death rate; investigations must be carried further in order that the relative importance of such influences as locality, season, age and sex, composition of the population, and other factors may be assessed. Then again, some of these crude rates are based upon data relating only to selected areas or groups of people and not to the whole population within the boundaries of the same territory. Under these circumstances it is clear such figures may give rise to dangerously misleading conclusions, a possibility envisaged by all responsible authorities, for official medical reports frequently observe that available data are so negligible in quantity and unreliable in quality, that any analyses of them, even with the most careful reservations, must inevitably prove misleading.

For example, whenever cancer incidence or mortality in our country happens to acquire news value, many of us will have heard it said that this dread disease never occurs among indigenous peoples in the tropical world. This statement is nothing less than rubbish, arising from the lack of data relating to this and other specific diseases in remote places. As a matter of hard fact, where authorities have been able to assemble the relevant facts, they clearly prove this legendary claim to be without foundation. Cases of cancer *do* occur among these peoples; their numbers increase yearly, but this does not necessarily mean that incidence is *actually* increasing, but rather that the mounting figures reflect a growing tendency on the part of the people to go to clinics and hospitals for treatment and advice, and thus new cases, previously overlooked, are being diagnosed. This example may suggest that existing hypotheses and theories about many diseases in the tropics must be removed from the realm of traditional conjecture to that of established scientific truth by the indisputable support of adequate and reliable data.

Perhaps I have said enough to justify the claim that progress in public health work and preventive medicine can be measured —the means are available though not always effectively applied; that specialized facts are essential items of knowledge fundamental to the smooth and efficient working of public health administrations wherever these may be established; that the analysis and interpretation of medico-statistical facts are matters demanding the careful attention of experts in their field of work if gross errors and misleading conclusions are to be avoided, and that more abundant and reliable facts in finer detail are urgently needed if future health programmes and policies are to be framed and health progress is to be accurately and regularly measured.

And finally, the difficult problems involved in post-war systems of administration will almost certainly have to be approached and solved from new angles. Preliminary to the tasks of reconstruction, it will be essential that responsible authorities shall have at their disposal a wide range of facts, the detailed study of which will in large measure, frame the outlines of the shape of things to come, for facts are the seeds of imaginative ideas which the wit of man often contrives to transmute into practical realities.

XII

THE FUTURE

By JULIAN S. HUXLEY, F.R.S.

IN his opening talk Mr. Wells spoke of the revolutionary nature of the changes through which we're now living. Indeed, we're living in the midst of one of the great historical world revolutions; and we are just beginning to realize this fact and all its tremendous implications. Mr. Wells also pointed out that this revolution was made possible by science and its applications.

In this series, we have heard about a good many of the scientific facts which have laid the foundations for this great change. The outstanding points grouped themselves in my mind under a few main heads. First, there was the astonishing increase in knowledge due to biological science, an increase which has been getting steadily more and more rapid. Think of what science has achieved within the last hundred years. We've discovered the three kinds of invisible organisms which cause disease—microscopic animal parasites, bacteria, and viruses. We've demonstrated that spontaneous generation is a myth. We've unravelled the mystery of heredity. We've described and named about a million separate species of animals, where the great Linnaeus less than two centuries ago could list no more than 4,400. We've found out what substances in our food are necessary, and how much of each: so that for the first time in history we can say precisely what is and what isn't an adequate diet for health. We have, again for the first time in history, collected statistics which give us a quantitative picture of our population and what's happening to it, in size and composition. We've obtained an understanding of how our bodies and those of other animals work, what they're made of, and how they react to a huge range of chemical substances.

Point number two: increased knowledge has meant increased power of control. Professor Witts told of the astonishing drugs which can kill the germs of disease inside us without damaging us—from quinine for malaria and salvarsan for syphillis to the sulphonamides for various bacteria. He also told of the equally striking drugs which conquer pain, from ether a century ago to our miraculous modern anæsthetics. Professor Haldane explained how our new knowledge of heredity enables us to synthesize new brands of living matter, such as potatoes for the arctic, or high-yielding and disease-resistant sugar-canes. Our knowledge of nutrition has given us a rationing scheme which has actually led to Britain being more healthily fed in war than in peace. Pasteur's discovery that spontaneous generation doesn't happen, together with our new knowledge of biochemistry, has led to the extraordinary developments in food preservation and storage of which Sir Edward Appleton spoke. Accurate knowledge about the habits of pests is the basis for their control, as described by Professor Munro and Mr. Fisher.

But my third point, that I think will also have been in listeners' minds, was that our power of control hasn't been used to the full—our new knowledge hasn't been properly applied. Even in the richest countries in the world, about a third of the people have been undernourished to some degree. In spite of quinine, malaria is still a major scourge, and the sulphonamide drugs have scarcely begun to play the role they might do. In spite of all our knowledge about the soil, wastage of our soil resources has during the present century been more serious than ever before.

What is the reason for this? Here we have my final main point. Whenever you attempt to apply new biological knowledge to human life, the problem ceases to be purely scientific. What was a biological problem becomes a social problem, and our scientific knowledge of social problems and our control of them is only in its infancy. We've learned how to control external nature, but not human nature or social processes. Though here I'm speaking only for myself, I expect that contributors to this series would all agree that the next big forward step in human evolution will come through our control of social and economic processes. Mass unemployment, over and under population, booms and slumps, ploughing in crops or pouring away milk when millions haven't enough to eat; monstrous unplanned ugly cities—those are the kind of things we need to understand and to get under control. It's no longer the forces of nature which threaten us. At the moment, blind social and economic forces which have come into existence as a by-product of our non-scientific civilization, are controlling us. We must control them, or perish; and the first step towards controlling them is to understand them.

Mr. Wells gave a vivid picture of the new possibilities open to man as a result of science. What he said made it clear that the changes we're now living through don't merely spell a revolution, but the greatest of all the revolutions that have happened since civilization began. I don't think I shall be misrepresenting him if I put his main points into rather a different form, and say that this is so because science, with its applications and its consequences, has for the first time converted a world where shortage has been inevitable into one where plenty could be possible; a world of overwork into one that could be a world with adequate leisure, and a world of hostile competing units into one that could be unified and peaceful.

Mr. Wells, quite rightly I believe, went on to say that we need a world control of power and industry, and that if we really did set up such a control, and were bold enough in our ideas and our enterprises, we would open up quite new possibilities of rich and adventurous living for all humanity. But such drastic new plans don't get made, still less adopted and put into practice, at one stroke. Human beings in the mass, at any rate in the present phase of our social evolution, unfortunately aren't guided by pure reason. As Professor Mackintosh said apropos of public health, reforms that seem obvious necessities after the event, are in *fact* met with the most determined opposition, and this springs from prejudice, from apathy (to which I would add ignorance), and from vested interests.

It seems to me—and here again I speak as an individual trying to see a little way ahead into the mists of the future—that we (and I mean all of us, not just scientists or statesmen) ought to clear our minds as to what the full extent of the next definite step in our human evolution is likely to be, and then concentrate our energies on realizing that advance as completely as possible: meanwhile we shouldn't bother too much about its being only one step, and that many more steps will have to be taken by later generations before we achieve the goals that the more clear-sighted can already perceive as possible and necessary.

In the past, all economic systems have been based on scarcity: there has never been enough to go round. In practice, this has always meant that some sections or classes of the population have had to go badly short in one way or another, like slaves in the days of slavery, serfs under Feudalism, or the working classes in the early industrial period—while a small ruling group or an exploiting or privileged class has had enough, and often to spare. To-day, however, the advance of science has made it possible, granted a certain reorganization of our economic and financial system, for everyone in a country like ours to have enough for health and a reasonable standard of security and decent living; on the other hand, for some time to come it won't be possible for everyone to enjoy real abundance and a high standard of living. So the first thing is to set up a decent minimum material standard—in food, health, housing, wages, and social security—below which no one will be allowed to fall. This will be the first time that equality will have been achieved in the material and economic sphere, even if it is only a minimum equality. Then we must use this minimum material standard as a platform on which to build a further minimum for all—a minimum standard of opportunity and development in non-material affairs, like education, leisure, recreation, culture, and participation in politics and government.

Internationally, we can't hope that the elaborate organizations we call nations will melt away overnight in favour of any fullfledged world government, such as Mr. Wells and *most* thinking people would like to see. But once more we can insist on certain minimum machinery on a world scale—for the control of key raw materials, for international policing and the prevention of war, for enforcing minimum labour and social standards, for international investment, for the planned development of backward regions, for training international staff.

Perhaps most important of all, we must have a new machinery of participation. In the past, most people have been driven to work by the lash of scarcity and the spur of competition. Scarcity is passing away, and the rigours of competition with it. A new driving force has to be found. This new incentive must be an incentive to co-operation. So far as I can see, it can only come from the feeling that all individuals are participating in a common job—something that is being done for everyone's benefit, not primarily for profit or in the interests of a group or section. The Russians seem to have developed this feeling that industrial work and other aspects of the development of the U.S.S.R. are *their* enterprise and *their* joint concern: it should not be beyond the democracies to make the same sort of thing come true for them.

Furthermore, if equality of opportunity, even on a minimum standard, is provided for all individuals, this implies a minimum set of common duties. One of the most important of these duties is that of being properly educated, and of understanding the problems of the day. And one of the best ways of fulfilling this duty is to take part in discussion groups and citizens' organizations of various kinds. The State must also do its share, by keeping in touch with public opinion, by providing for adult education, by explaining its administrative problems, by encouraging the production of good documentary films, by commissioning artists and writers to record and interpret the contemporary scene.

In all of this science has an important part to play. In the natural sciences our progress, striking though it has been, could be much more rapid if we had more scientists. Before the war the United States, in proportion to national income, spent on scientific research five or six times, and Russia about eight times, as much as Britain. The war has seen an improvement, and we must make up our minds that 1 per cent of our national income (in place of one-tenth of 1 per cent, as before the war) should be our minimum investment in scientific research, and would bring in an enormous return.

The war has taught us some important things about getting the best return out of science. In the services, research has largely become operational—that is, the scientists go out into the field. The boys in the back room don't stay there all the time. They're sent out to the battlefronts to find out the detailed needs of the men on the job, to study how the weapons and devices that have been produced as a result of research in the back rooms and laboratories at home stand up in actual fighting.

We still need the same thing in peace-time; instead of science sticking in university laboratories, or being tied down to research in the interests of producers, it must go out into the field and must find out the needs of consumers. Already the soil experts and agricultural scientists are studying the needs of farmers and farming, on the Russian steppes, in our own countryside, in the Tennessee Valley, in the Middle East. Already technical experts are beginning to survey the needs of the common man in building and household equipment. We want peace-time operational research, everywhere and on the largest possible scale, and the ordinary man and woman must help by clearing their minds as to what they really need.

Then there must be an enormous extension of scientific research and the scientific spirit into social affairs. Major Edge in his talk showed how the statistical surveys made by the Census are indispensable tools for public health authorities. The same technique of survey—dispassionate and quantitative—can be applied in nearly every field, to test how far our knowledge falls short of being applied. In this country we're beginning to apply this method to diet—to see how far we lag behind the standard of healthy nutrition and how the lag differs in different regions. We need social experiments—regional plans, like the Tennessee Valley scheme; the introduction of extra milk or nursery schools in one area, and then comparing the results with "control" areas. In general, we—and again that's all of us—want politicians and civil servants to understand what the scientific spirit means, to realize the need for collecting facts before embarking on a policy, and then for constantly checking the policy against the facts, instead of against party advantage or preconceived ideas.

Perhaps most of all, we need a realization by the general public of what science is doing and what it *could* do. Science, as my grandfather T. H. Huxley once said, is organized common-sense. The scientific spirit means scrapping prejudice and mere tradition or authority and replacing them by an appeal to fact. As we get fuller knowledge, the answer to our problems will be dictated less and less by the play of conflicting political interests, more and more by the logic of the facts. But knowledge won't be effective if it is confined to a few experts: it must be part of the general atmosphere. The people at large *must* understand what science can and can't do; must realize that *their* understanding can help science to get on with its job.

The Prime Minister in his recent broadcast introduced a new idea into our politics—a national four-year plan as a method for getting things done. I personally think it is an admirable idea—perhaps the only technique for unifying national energies in peace as they can be unified by war. But a plan, if it's to succeed, must be scientific. So I appeal to the millions of listeners who I know have been interested in this series, to follow up that interest, to go on learning all they can about this vital subject, so as to be able to make up their minds on the practical possibilities for after the war. What has science already discovered which could be brought into the plan? What more could be done to apply existing scientific knowledge in the plan? How should the tremendous potentialities of science be harnessed now, to serve the future in general and our national four-year plan in particular? Man won't come into his heritage by leaving everything to the experts: it's up to all of us.

THE END